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THE DIFFERENTIATION OF BRONCHIOGENIC CARCINOMAS*

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THE hopelessness with which cancer of any organ is regarded by the laity is reflected somewhat in the average physician's attitude toward bronchiogenic carcinoma. This attitude will continue to be one of hopelessness as long as cancer of the lung is considered a single disorder; as long as it is believed that a negative bronchoscopy rules out malignancy in from 75 to 85 per cent of cases; and as long as radiography is delayed until physical signs appear. An attitude of pessimism will prevail if it is believed that bronchiogenic carcinoma is clinically silent during the first half of its existence; if a policy of "watchful waiting" is regarded as a means of diagnosis, especially if during this period of observation the cancer extends beyond resectability. Too frequently precious time, the chief factor distinguishing curable from incurable cancer, is lost during the period in which a dry cough "should clear up," or between the occurrence of hemoptysis and a careful investigation for its cause. Such delay may be an economic compromise or a consequence of inadequate diagnostic facilities, but occasionally it is adopted without thought of therapy because the disease is considered hopeless in the beginning.

Bronchial carcinoma, like cancer elsewhere, is a disease of later life; however, many of its victims are middle-aged, and others are good surgical risks despite their years. Naturally, it is disheartening to see an

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inoperable squamous-cell carcinoma in a 50-year-old man who has been "doctoring for half a year"; nevertheless, such occurrences should not provoke pessimism. On the basis of the excellent work of Koletsky,[1] the study of a series of cases, and my own observations, I believe that many bronchiogenic carcinomas are curable at the time of the onset of symptoms and that total pulmonectomy is a logical operation, a precise and truly surgical procedure. I should like to promote this conception to a wider acceptance.

My purpose, therefore, is first, to show that cancer of the lung cannot be regarded pathologically or clinically as a single entity; second, to indicate the diagnostic value of bronchoscopy in early cases; and finally, to show that time is really precious and that in many cases there is no significant silent period, but that symptoms tend to occur early. If they do occur early, and if too much significance is not attached to a negative bronchoscopy, and if we have a good fundamental knowledge of the clinical and pathologic behavior of bronchiogenic carcinoma, then perhaps we can fulfill Harvey's[2] ideal for the future, "Early diagnosis leading to radical treatment." Possibly in the future fullest use will be made of all available biologic, endoscopic, and radiologic methods of diagnosis;[3] and then, perhaps, we can supply better prognosis, perform fewer needless operations, reduce operative mortality, and increase the incidence of cures.

PATHOLOGICO-CLINICAL DIFFERENTIATION

This paper is based on the study of 216 patients admitted to Cleveland City Hospital whose cases were diagnosed primary carcinoma of the lung; 158 were histologically proved. In thirty-two the clinical diagnosis was regarded as correct; twenty-six were discarded as possibly misdiagnosed. Of the histologically proved cases, there were fifty-three small-cell carcinomas, thirty-two adenocarcinomas, and sixty-one squamous-cell carcinomas; five were diagnosed carcinoma simplex, and in seven there was insufficient material to make a diagnosis of tumor type (aspiration biopsies, pleural fluid).

Koletsky has reported the results of his study of 100 of the autopsied cases in this series. On the basis of histologic character, he recognized three essential types of bronchiogenic carcinoma: namely, small-cell carcinoma, adenocarcinoma, and squamous-cell carcinoma, which differed in the site of origin, rapidity of growth, and mode of extension and metastasis. The prominent distinctive features were those of type and not simply dependent on the degree of histologic differentiation. The latter did not seem to particularly influence the morbid anatomy of each type, nor cause one to resemble another; neither did it confuse the microscopic picture so that biopsy of the primary tumor was not indicative of type. As well as a correlation between cell type and gross morbid anatomy, Koletsky found a relationship between the latter and the clinical behavior and prognosis. The additional cases in this series

support these concepts. By careful clinical, bronchoscopic, and radiologic study it has been found possible to predict tumor cell type in the majority of cases before histologic examination.

Small-Cell Carcinoma.—Sixty-six per cent of these tumors arise in the main stem bronchi. The remainder frequently begin near the orifice of a secondary branch; rarely, the site of origin is in a small branch bronchus. The formation of an irregular mediastinal mass is characteristic of this centrally located and rapidly growing tumor. It is highly invasive, extends along the bronchus, and surrounds it and neighboring structures with firm tumor. This process is accompanied by a nonselective invasion of the adjacent lung. The involvement of pulmonary parenchyma, however, is less conspicuous than the mediastinal extension which is vigorously metastatic to adjacent, regional, and distant lymph nodes (Fig. 1).

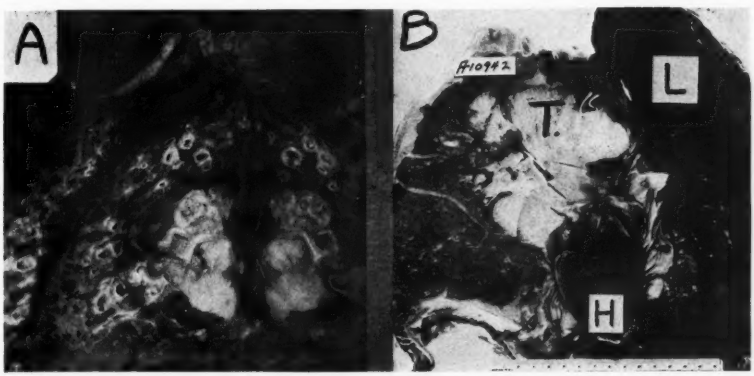


Fig. 1.—*A*, Surgical specimen. Right lung containing a local tumor mass, a rather early small-cell carcinoma. Death occurred on the twelfth postoperative day following sudden hemorrhage from the inferior pulmonary vein. The tumor arose in the orifice of the right lower lobe. Thirty-six autopsy sections of the mediastinum revealed microscopic tumor in one lymph node.

B, Autopsy specimen. Both lungs and heart. Huge mediastinal mass arising in the right main bronchus. Small-cell carcinoma with extensive mediastinal involvement, invasion of the heart, and occlusion of the superior vena cava and the bronchus. *T*, Tumor mass; *H*, heart; *L*, left lung. (See Fig. 8, *B* and *BB*.)

Early symptoms are cough and vague thoracic sensations. Hemoptysis may occur early but is more commonly a late symptom; it usually follows mucosal ulceration by tumorous invasion, or infection consequent to partial bronchial occlusion. As a rule, the former is only extensive at a late stage, and the latter tends to occur only after the tumor has grown to a good size. This follows the usual location of these tumors about large, rigid bronchi, deep in the mediastinum. Occasionally, but not commonly, the first symptoms which seem to warrant medical attention arise from metastases in the cervical lymph nodes or within the cranium, or from the involvement of mediastinal structures. Hoarseness may result from involvement of the vagus or recurrent laryngeal nerves; dyspnea and wheezing from bronchial occlusion or tracheal

compression; dysphagia from esophageal compression; and swelling of the upper body from vena cava compression. Such symptoms and findings may be the dominant features of the initial examination, but, as a rule, they were preceded by cough, chest pain, and even considerable weight loss.

It is a common belief that the properties which characterize a tumor as malignant are more pronounced when the tumor's victim is young. In a sense, this is true of the small-cell carcinoma which tends to occur in younger individuals (average age 47) than does adenocarcinoma or squamous-cell carcinoma. However, it does occur in the seventh decade, and in one instance a patient aged 35 survived for four years. It does not seem logical to infer that the small-cell type of tumor is only a highly malignant variety of a single disease, and not a distinct type of tumor.

Adenocarcinoma.—In this series the adenocarcinomas arose in secondary branches, such as the lobar stems, in 70 per cent of the cases; in small branch bronchi, in 20 per cent; and in the main bronchi, in 10 per cent. The central extension of this tumor is less striking than its peripheral growth which follows the bronchial and vascular channels. The rapidity of its growth varies somewhat with the degree of cellular differentiation but is less marked than that of the small-cell tumors. Because of its tendency to arise in secondary bronchi and small branch bronchi, it may form a well-circumscribed mass which replaces pulmonary parenchyma and which appears as a nodule within the lung. Such a location, in the richly vascular pulmonary tissue, is favorable for widespread and extensive blood-borne metastases, a common finding at autopsy. Lymphatic metastases are generous. There may be diffuse involvement of the mediastinal lymph nodes, with the formation of irregular masses. Involvement of the peripheral lymphatics may invoke pleural effusion, which may be bloody. In one instance there was fatal hemorrhage into the pleural space from a small peripheral tumor which had not metastasized.

On three occasions I have seen a peculiar gross behavior of adenocarcinoma which is rather striking. Because my experience is limited, I feel that this behavior may be rather common. In all three instances it was observed relatively early. One would expect full tumor growth to obscure this anatomic detail, so that it might not be detectable at autopsy. The tumor apparently arises deep in the bronchial structure, perhaps in a mucous duct or gland; it grows from there into the bronchus by perforating the wall between plaques of cartilage, thus forming a pedunculated, polypoid, intrabronchial mass (Fig. 2). Its growth external to the bronchus likewise is a circumscribed mass, and the entire tumor, therefore, is more or less bilobed, or like a "cottage loaf" as Brock[4] has so aptly put it. He, however, was referring to benign adenomatous polyps. In two of these three instances, the patients died with metastases (Fig. 3, *I* and *II*).

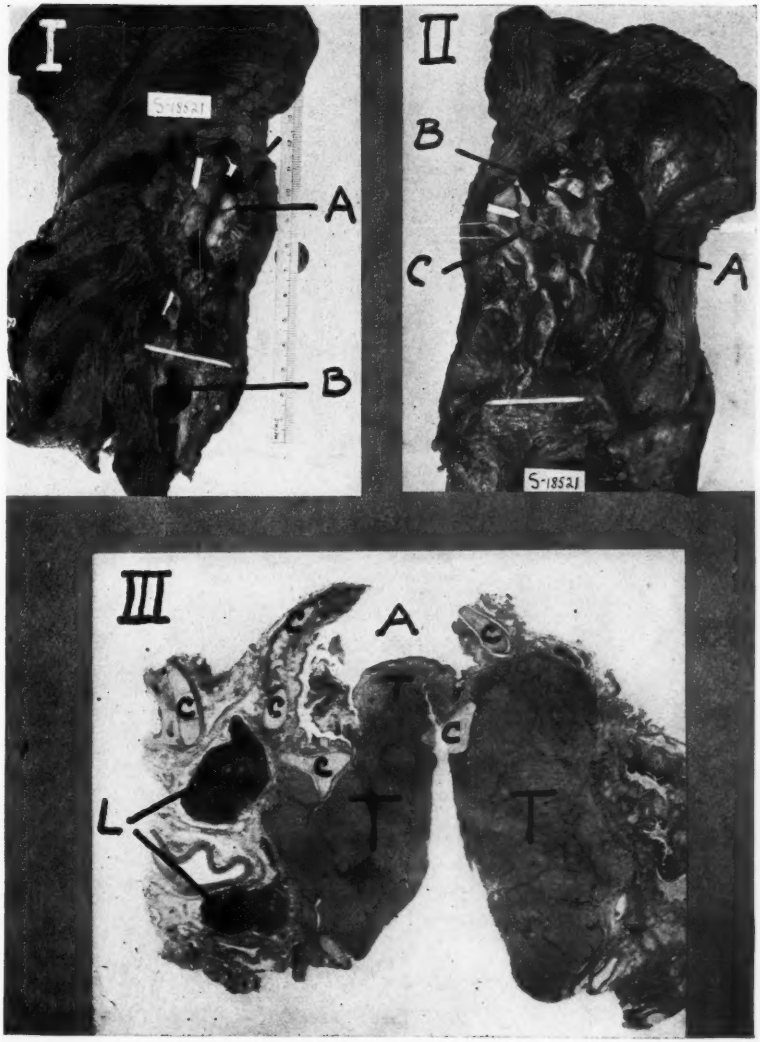


Fig. 2.—Surgical specimen of left lung, demonstrating a sharply circumscribed, well-differentiated adenocarcinoma of the main bronchus, with an acute tuberculous abscess in the lower lobe.

I, Posterior view of specimen with an incision in the tumor, *A*. *B* indicates the abscess in the lower lobe.

II, View of hilum. *A* indicates the bronchus which has been laid open; *B*, the upper lobe orifice; *C*, perforation of tumor and protrusion into the bronchus.

III, Photograph of a paraffin section of the entire tumor and the left main bronchus. The major portion of the tumor is without the bronchus and the minor portion enters the bronchial lumen between the cartilages. *A*, Bronchial lumen; *C*, bronchial cartilages; *T*, tumor; *L*, lymph nodes.

The short duration of the patient's illness and the rapid production of complete bronchial occlusion are the only facts which strongly favor the opinion that this tumor is not a benign adenoma. The fact that the patient is living and well more than two years following operation is not necessarily an argument against malignancy.

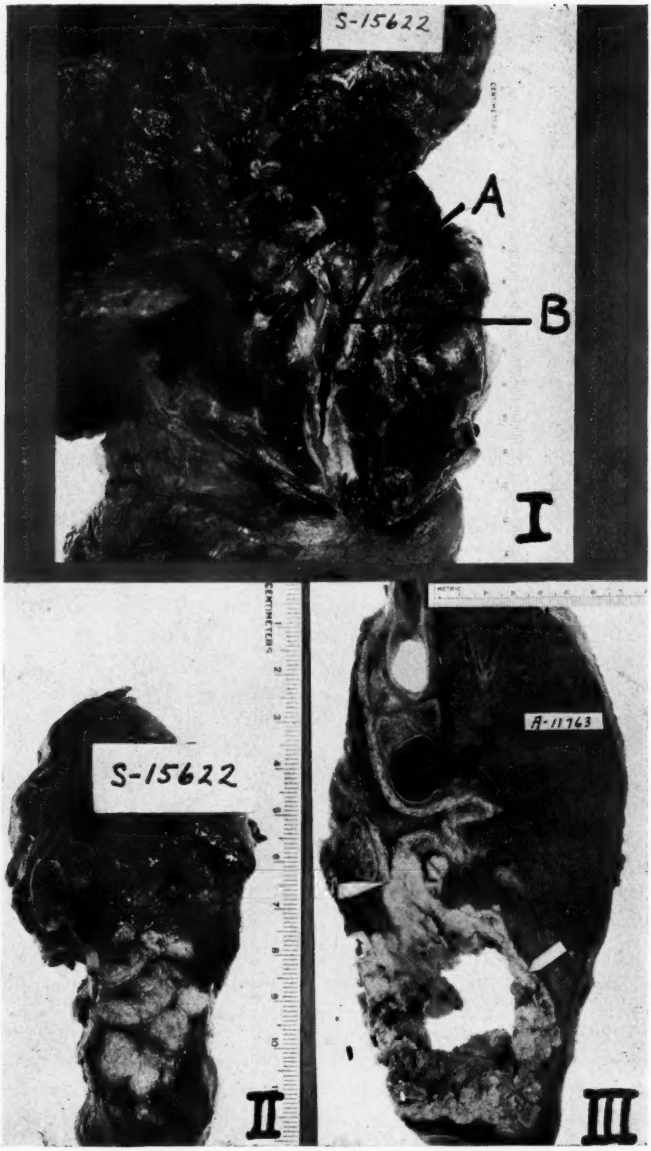


Fig. 3.—*I*, Surgical specimen of right lung, showing view of hilum. *A* points to the main bronchus which has been laid open and a portion removed. The defect reveals tumor just without the bronchus. *B* points to two crescentic defects in the bronchial wall where a polypoid tumor had protruded. At bronchoscopy it appeared to be a benign adenoma. Biopsy showed well-differentiated adenocarcinoma. The large mass of tumor, which existed outside the main bronchus, is shown in *II*. The patient died eighteen months after operation from recurrence of the tumor.

III, Autopsy specimen, showing left lung with a huge squamous-cell carcinoma exhibiting a large cavity. The tumor arose in the lower lobe bronchus. Note the peribronchial extension.

While benign adenomas have a predilection for women,[4] adenocarcinoma affects the same sex in 28 per cent of cases in striking contrast to 5 per cent in the small-cell and squamous-cell types. This mild similarity in sex affectation and in the occurrence of a detail in gross pathologic behavior may mean nothing, or it may be a feature of any early adenomatous tumor of the bronchus. It may also indicate, however, that a more profound relationship exists between benign bronchial adenomas and bronchiogenic adenocarcinoma.

Hemoptysis and pleural pain seem to be early symptoms more frequently in adenocarcinoma than in small-cell carcinoma. The pulmonary symptoms are occasionally absent or deemed insignificant, and the presenting complaint may arise from metastases. The average age in this group was 51 years, above that of the small-cell group. The average duration of life from the onset of notable symptoms to death was eight months.

Squamous-Cell Carcinoma.—In 70 per cent of instances this tumor originates in the first branches of the main stem bronchi. It apparently grows more slowly and affects older persons than either of the other two types, the average duration being twelve months, and the average age, 55 years. Local growth of the primary tumor results in the formation of a nodular mass about the bronchus of origin. In an early radiograph this may appear as a fairly well-circumscribed area of density, which has a tendency to central necrosis and cavitation. What role infection plays in this process cannot be stated when the cavitation occurs early. However, late in the disease, and especially at autopsy, it seems that infection plays a significant part. We know that it always does in long-standing bronchial obstruction. Such a state is common in the course of this slowly growing tumor, for it extends centrally along the bronchus, causing a fixation and constriction of this structure. This extension is not by way of lymphatics, and although it is invasive, it seems to avoid lymph nodes. It is extrabronchial in its proximal portion so that the lumen of the constricted bronchus may reveal mucosal tumor only deep within the entire mass. Peripheral growth of the mass is likewise invasive. Upper lobe tumors are prone to extend into the upper thoracic aperture, or into the chest wall, disturbing the function of adjacent structures. Such extension may be unaccompanied by notable metastases in the mediastinum. In general, this tumor seems to metastasize late and, even then, not nearly as extensively as small-cell carcinoma and adenocarcinoma. In contrast to these two types, the squamous-cell tumors exhibit cavity in over 50 per cent of autopsy cases. The cavity usually communicates with the involved bronchus and occupies the center of the peripheral tumor mass (Fig. 3, *III*).

The earliest symptom is usually cough which is productive. Pink or bloodstreaked sputum is quite common. The onset is rather in-

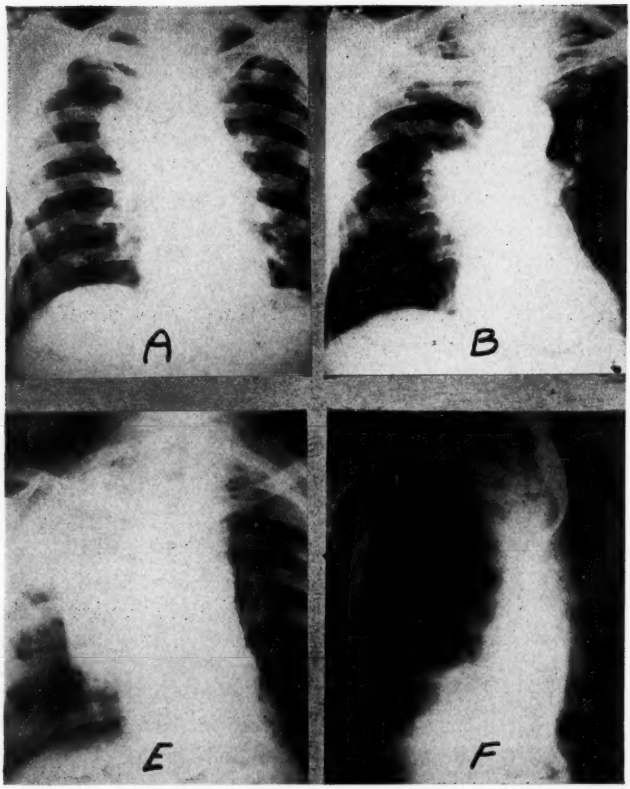
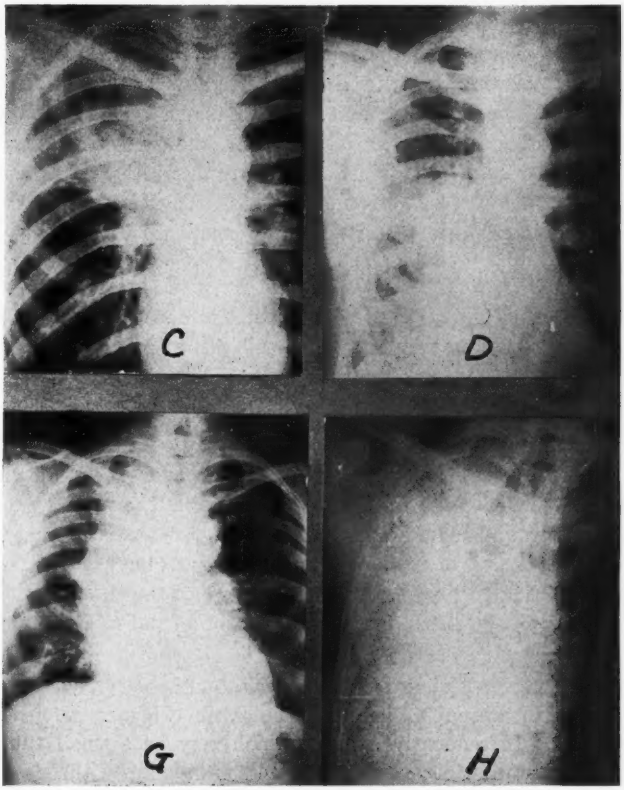


Fig. 4.—Eight examples of small-cell carcinoma. *A*, *B*, and *C* had symptoms for from one to two months. There is a rather poorly defined, dense, irregular mass blending with the mediastinum in each instance. *D* had symptoms for six months; the mass is large and there is considerable infiltration in the lower lobe. *E*, *F*, *G*, and *H* had

(*Continued on next page.*)

sidious, and the presenting illness may be of months' duration. Tumors high in the apex or near the parietal pleura are commonly accompanied by severe pain and may involve the brachial plexus or cervical sympathetic system. Later, infection with fever, productive cough, and weight loss are outstanding symptoms.

At the time that a maladjustment of natural phenomena occurs within a person, and as a result a few epithelial cells within the lung exchange their properties of function for increased growth and reproductive abilities and in such fashion become a bronchiogenic carcinoma, perhaps it would be difficult to separate one type of cancer from another. However, from this beginning, whether it is a common one or not, the subsequent courses are ordinarily divergent, and occur in three fundamental modes until the cancer destroys itself by killing its host. At



symptoms for from six to nine months. *E* shows beginning atelectasis; the patient had superior vena cava obstruction and hoarseness. *F* shows marked distortion of the esophagus. *G* shows a huge mediastinal mass without atelectasis. The patient had severe symptoms of mediastinal obstruction. *H* shows complete atelectasis of the right lung; usually a very late occurrence in small-cell carcinoma.

this time, at autopsy, we find the three essential types of bronchiogenic carcinoma as described by Koletsky. At this time, also, the distinguishing features which characterize each type are the most prominent. One wonders if such distinction can be made during life or early in the course of these tumors. This study indicates that it can be in the majority of patients; and, therefore, it is believed that each type has its own peculiarities at the onset, and that these differences become more pronounced as the disease advances. There are instances in which the characteristic features overlap, so that even the gross pathologic findings are not entirely conclusive and histologic study alone is differentiating. Naturally, there are even more such instances when only clinical data are available. Nevertheless, these instances are not the rule, and, in general, the gross morbid anatomy is reflected well enough in the clinical picture to enable one to separate the three essential types by such means as the combination of radiography and bronchoscopy.

RADIOLOGIC DIFFERENTIATION

Ordinarily each type of tumor produces a rather characteristic radiograph which, of course, is varied by the age and location of the tumor, the degree of bronchial obstruction and inflammation, and peculiarities of the host. Despite these variable factors, the gross morbid anatomy is distinctive enough to produce a radiograph which is frequently indicative of tumor type. Sometimes this is true relatively early in the disease, and later other factors, such as complete bronchial occlusion, hydrothorax, and infection, mask the true morbid anatomy and the radiograph is not distinctive.

Small-Cell Carcinoma (Fig. 4).—Early in the course of this tumor, about the time troublesome symptoms begin, it is not unusual to see an irregular mass in the radiograph which blends with the mediastinum and does not have a sharp outline. Surrounding infiltration, which is mostly inflammatory, is usually scanty, but may be rather extensive and clear spontaneously. Lobar atelectasis is not common except when the primary tumor arises in a secondary bronchus. The primary mass enlarges rapidly and extends principally into the mediastinum, thereby producing distortion of the mediastinal structures but usually not much atelectasis. Finally, there is severe "choking" of the mediastinum which may or may not be accompanied by main bronchial occlusion.

Adenocarcinoma (Fig. 5).—The early radiograph frequently displays a sharply circumscribed, dense mass which, for the most part, is separate from the mediastinum. There is usually no evidence of mediastinal involvement. Infrequently a mass, which may be a small tumor and still the source of widespread metastases, is hidden by the mediastinal shadow. However, if the primary tumor is not visible and has not produced some atelectasis, in all probability it is an operable, local tumor. Late in the disease there is little to distinguish adenocarcinoma from the other types besides the fact that it is more prone to produce secondary tumor nodules in both lungs. There may be a large mass of mediastinal tumor simulating small-cell carcinoma; and rarely the primary tumor cavitates, thus simulating the squamous-cell type.

Squamous-Cell Carcinoma (Fig. 6).—The early radiograph portrays a nodule in the lung which is not entirely peripheral and less sharply circumscribed than the primary adenocarcinoma. The original tumor may be indistinct because of surrounding inflammatory infiltration, a rather common accompaniment. Growth of the tumor tends to produce occlusion of a secondary bronchus (where it originates in 70 per cent of cases) and to cause a simple lobar atelectasis. Necrosis and cavitation of the primary tumor may occur early and make the radiograph indistinguishable from that of lung abscess. In the course of time the tumor extends along the bronchus into the mediastinum and peripherally into the lung. It may thus produce multilobar atelectasis,

form a giant cavity, extend into the chest wall, or into the thoracic inlet, and interfere with contiguous structures.

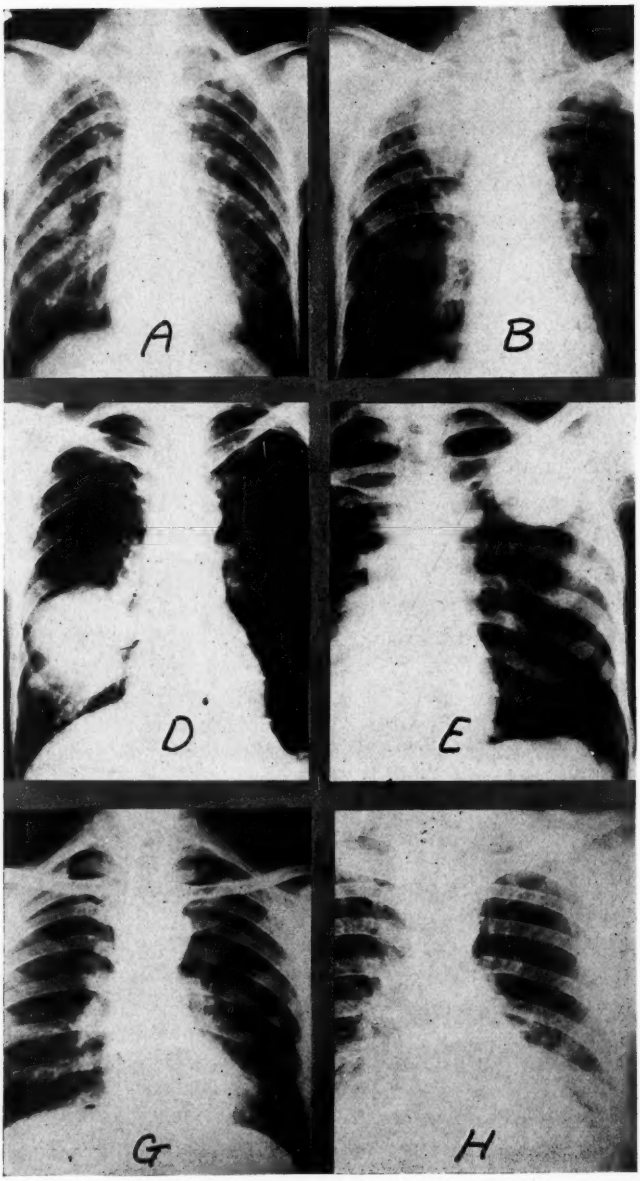
The inference that the radiograph is a super-microphotograph that labels bronchiogenic carcinoma one type or another is not intended, but it is hoped that the accompanying figures and statements portray the relationship existing between the gross morbid changes of each tumor type and the clinical picture they produce. In many instances, late in the disease, it is possible to obtain an "inside" view of the morbid anatomy by bronchoscopy, and such observations combined with clinical and radiologic studies often provide a complete picture.

BRONCHOSCOPIC DIFFERENTIATION

Small-Cell Carcinoma (Fig. 7, *I*).—Because of a frequent origin in the main bronchus and because of a tendency to form a large mediastinal mass, the majority of small-cell tumors present typical bronchoscopic findings of which the most common are extreme distortion and fixation. When bronchoscopy is performed late in the disease, the tracheobronchial tree is firmly fixed. The lower trachea may be compressed; enlarged lymph nodes deforming the soft posterior tracheal wall may be palpated with the lip of the instrument. The growth of tumor at the bifurcation tends to pry the main bronchi apart. If this takes place rapidly and is observed shortly after its occurrence, the mucosal edge of the carina may still be sharp, although the angle of bifurcation is much widened. This finding is not unusual in recent inflammatory enlargement of the bifurcation lymph nodes. Later on, the carina becomes a rounded surface rather than a sharp edge. The mediastinal mass may compress the bronchial lumen into a narrow slit, so that it is impossible to see distally where the tumor has broken through the mucosa. At other times the involved bronchus may be an irregular, tubular structure of tumor, which is not occlusive and provides ample areas for biopsy.

Adenocarcinoma (Fig. 7, *II*).—Bronchoscopy may be entirely negative despite a good-sized tumor within the pulmonary parenchyma. On the other hand, the findings may be suggestive of an entirely endobronchial tumor. How this tumor perforated the bronchus in three cases has been mentioned above; it has not been observed in any other malignant tumor. Late in the disease there may be extensive mediastinal involvement, with deformity of the central portion of the tracheobronchial tree such as one sees in small-cell carcinoma. However, the fixation is somewhat less because the tumor occurs in partially separate masses, at the sites of lymph node concentrations, rather than in a single large tumor.

Squamous-Cell Carcinoma (Fig. 7, *III*).—On rare occasions, when this tumor originates in the main bronchus and bronchoscopy is performed very late, the findings may simulate those observed in small-cell tumors. As a rule, they are quite different. When the upper lobe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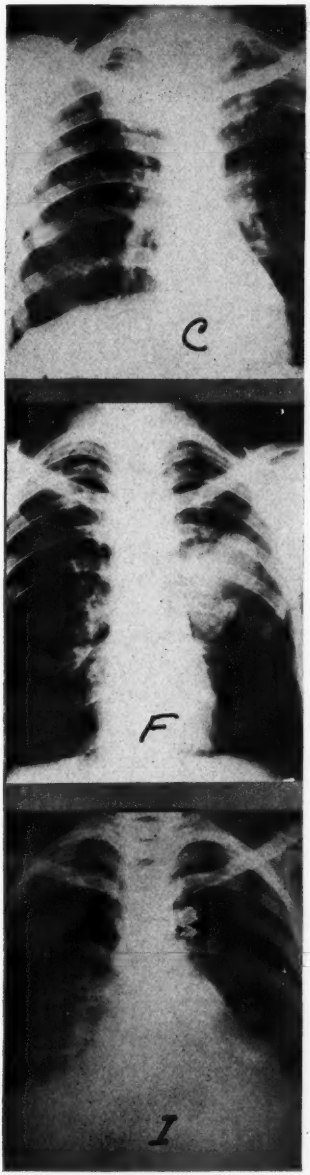

Fig. 5.—Nine cases of adenocarcinoma. *A*, *B*, *C*, *D* and *E* had symptoms for from one to six months. Each presents a sharply circumscribed, fairly regular, dense mass which is more or less separate from the hilum. *F* had symptoms for eight months. *G*, *H*, and *I* had tumors hidden by the mediastinal shadow. In *G* it was found in the left lower lobe bronchus by bronchography; in *H*, in the left main bronchus at bronchoscopy; in *I*, in the right upper lobe bronchus at autopsy. This radiograph was interpreted to indicate congestive heart failure. Tumor cells were present in bilateral pleural effusions. There were widespread metastases. Autopsy was performed three weeks after this radiograph. Complete removal of the tumor was accomplished in *D*. The patient died from pulmonary edema following thoracoplasty which was done three weeks after pulmonectomy. Autopsy revealed no tumor. *H* is an early radiograph of the case in Fig. 2.

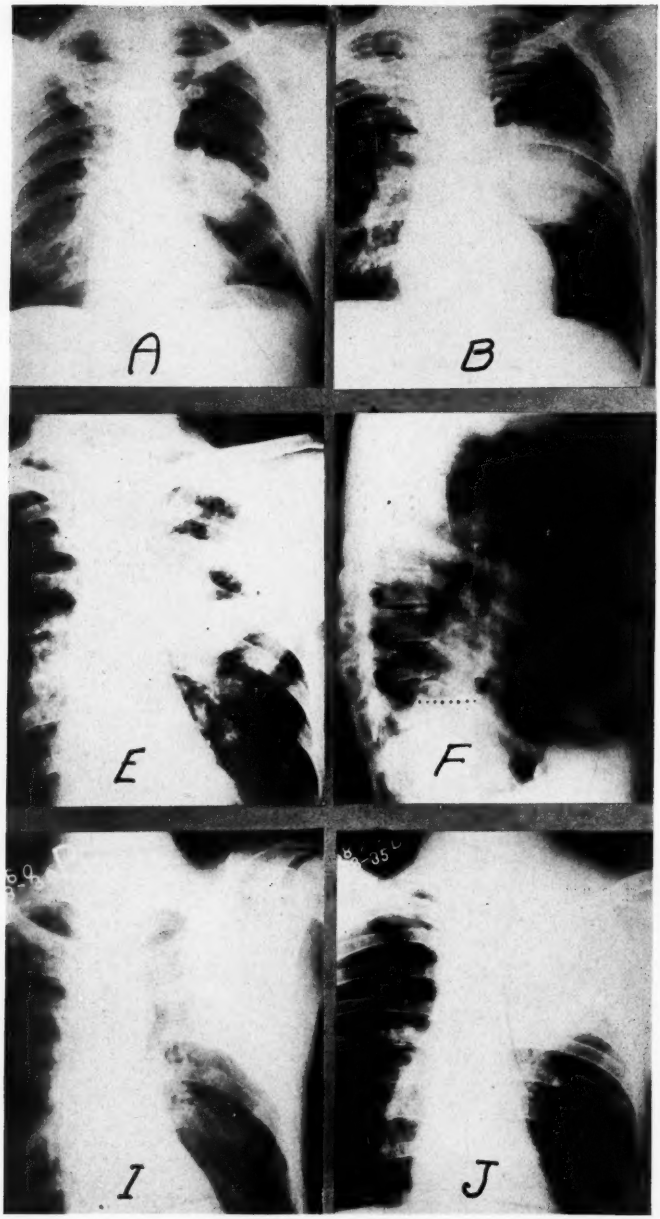

Fig. 6.—Eleven cases of squamous-cell carcinoma. *A* and *B* had symptoms for two months. The shadows are not as sharp or as dense as those seen in the adenocarcinomas. They do not blend with the mediastinal shadow as in early small-cell or main bronchus tumors. *C* shows a typical lobar atelectasis. *D* portrays a drowned upper lobe simulating pneumonic consolidation. In *E* and *F* there is cavitation of the

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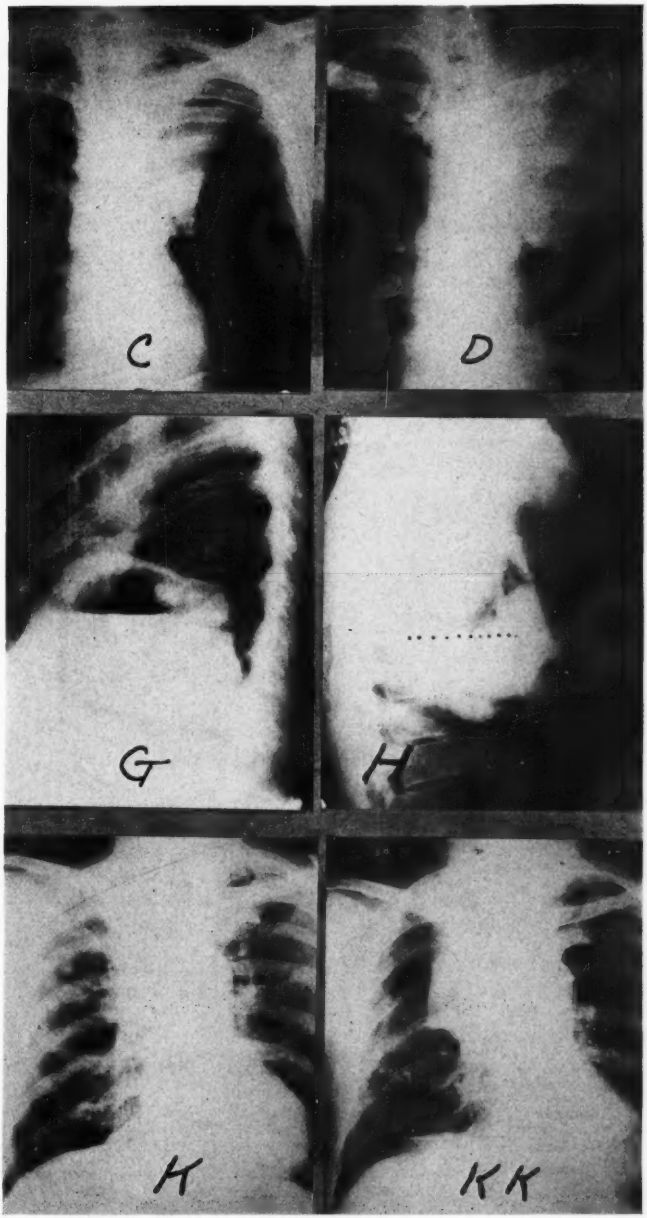


primary tumor mass, simulating lung abscess. *G* and *H* demonstrate giant cavities probably resulting from the necrosis of tumor which has almost completely replaced an entire lobe. *I* shows involvement of the chest wall, a behavior which seems uncommon in other than squamous-cell tumors. *J* and *K* had extension into the upper thoracic aperture, a behavior which is not unusual in squamous-cell tumors arising in the upper lobe bronchi. *KK* was made after the institution of pneumothorax.

bronchus is involved, bronchoscopy may be negative; however, if the bronchus is occluded, there is a telltale mediastinal shift and a slight climb of the hilum which increases the normal curvature of the main stem with the upper lobe bronchus; thus, it may be impossible to see its orifice. Occasionally a retrograde telescope will permit visualization

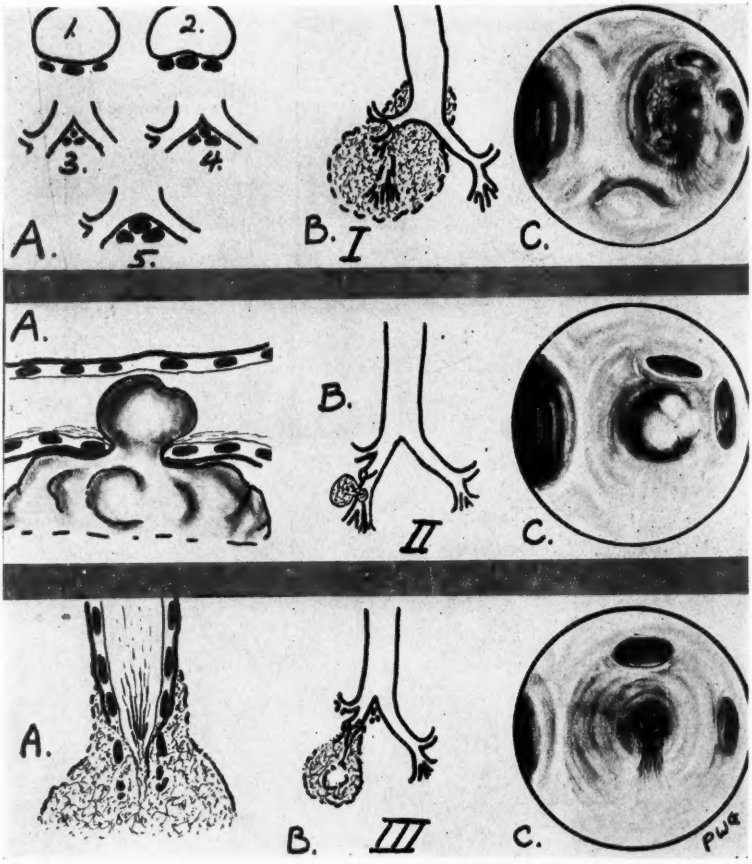


Fig. 7.—*I*, Small-cell carcinoma. *A* shows effect of enlarging lymph nodes on the tracheal cross section, and on the carina and bifurcation. *B*, Diagrammatic representation of a small-cell mediastinal mass arising in the right main bronchus. *C*, Drawing of a rather common picture at bronchoscopy. The angle of bifurcation is widened and the carina rounded. The posterior tracheal wall is irregular because of enlarged lymph nodes. Although the main bronchus is compressed, it is still patent.

II, Adenocarcinoma. *A*, Diagnostic sketch of bronchial perforation by adenomatous tumor. *B* and *C* indicate how such a tumor may appear to be entirely endobronchial. This has been observed three times in a rather small series. No other bronchoscopic finding has been noted as characteristic of adenocarcinoma alone. (See Figs. 2 and 3.)

III, Squamous-cell carcinoma. *A*, Sketch demonstrating how extrabronchial tumor may compress the bronchus and accentuate the longitudinal mucosal folds. This has been a frequent observation in squamous-cell tumors. *B*, Diagrammatic representation of a cavitating squamous-cell tumor arising in the right lower lobe bronchus. *C* indicates how it may appear through the bronchoscope. Normal bifurcation; main stem bronchus fixed; contracted lower lobe bronchus with deep longitudinal mucosa folds above the visible tumor.

of a deformed bronchus, but a biopsy must be taken blindly. At other times, a diagnosis can be made, without visualization of the tumor, from the displacement and contraction of the upper lobe orifice and the degree of bronchial fixation. Tumors arising in the other lobar bronchi are usually visible. There may be no deformity of the carina and bifurcation even late in the disease.

This tumor extends peribronchially. It tends to spare lymph nodes and the bronchial mucosa at its advancing edge. We usually see an ulcerostenotic lesion, at the site of origin deep in the bronchus, with a conical constriction above it. This latter deformity is one of contraction produced by the extramucosal infiltration of tumor. It fixes the bronchus in a contracted state, greatly accentuating the normal longitudinal mucosal folds. Later the tumor extends into the mucosa, and with the aid of infection produces a contracted, angry red bronchus almost replaced by tumor. This change may extend to within 1 or 2 cm. of the carina without the production of notable deformity of the bifurcation. Such peribronchial extension may invade a large vessel and cause death by hemorrhage; in the lower lobe bronchi it may surround and involve the inferior pulmonary vein in the apex of the pulmonary ligament and make surgical removal impossible. In left upper bronchial tumors, it may involve the recurrent laryngeal nerve long before tumor gains the lumen of the main bronchus.

It must be remembered that the radiologic and bronchoscopic differences as depicted above are merely reflections of gross morbid anatomy, and that in some instances the latter is not entirely differentiating. These instances, however, are exceptions to the rule. An attempt was made, after shuffling the cases in this series, to guess the type of tumor from a study of the clinical record obtained on admission, the admission chest roentgenogram, and the bronchoscopic findings. A correct guess was made in 90 per cent of the squamous-cell tumors, in 55 per cent of the small-cell tumors, and in 20 per cent of the adenocarcinomas, so that in the entire group it was possible to name correctly before biopsy the type of tumor in over 60 per cent of cases.

THE DIAGNOSTIC VALUE OF EARLY BRONCHOSCOPY

In this series a positive biopsy was obtained in 72 per cent of more than 100 bronchoscopies, and a diagnosis of carcinoma was made in 87 per cent of patients. At times, although there is little doubt in the diagnosis, it is impossible to obtain tissue for examination. These figures are similar to those found in the current literature and are in keeping with the observation that about 25 per cent of autopsy cases fail to reveal tumor which would be accessible for biopsy. The literature abounds with the statement that a positive biopsy can be obtained by bronchoscopy in 75 to 85 per cent of patients with bronchiogenic carcinoma. Such statements are misleading, for they are based on a rationale which has no regard for time and are frequently interpreted

to mean that a negative bronchoscopy rules out cancer in 75 per cent of cases. A tumor may be a small, peripheral nodule when it first causes hemoptysis and a large mediastinal mass when it is first observed bronchoscopically; so it is most important to consider the time of examination in relation to the onset of symptoms. It has been said, "By the time they're bronchoscoped they're too far gone to carry their own x-rays." In this series much of the clinical material is practically autopsy material, for the average duration of life from admission to death is only one month. Figures based on findings at this stage of the disease cannot be applied to patients examined at the onset of symptoms, which is the time a diagnosis should be made if there is ever to be any significant therapeusis for bronchiogenic carcinoma.

Assuming that symptoms generally occur early, we can estimate the value of early bronchoscopy by studying the tumor incidence in that portion of the bronchial tree within range of the bronscope. In this series 35 per cent of the tumors arose in the main bronchi, 26 per cent in the upper lobe bronchi, 26 per cent in the lower lobe bronchi, and 13 per cent in the middle lobe bronchus or in small branch bronchi. Very few of the upper lobe tumors, none of the branch bronchus tumors, and not all the lower lobe tumors would be visible early in their course. In all probability, if performed early, bronchoscopy will be negative in roughly 40 per cent of cases. If we consider squamous-cell carcinoma separately (the most common type of tumor and the most favorable for excision), we find that 49 per cent originate in the upper lobe or small branch bronchi. These are not likely to be accessible for biopsy until rather late in the disease. It seems logical to conclude that, in a patient with a short history in whom there is reason to suspect bronchial malignancy, a negative bronchoscopy means only that bronchography, sputum examination for tumor cells, aspiration biopsy, or thoracoscopy should be performed until there is sufficient evidence to warrant exploration or a diagnosis is established. For if tumor is being dealt with, it is probably operable and one should not "wait to see what happens."

DURATION AND ONSET OF SYMPTOMS

The average period between the beginning of a bronchiogenic carcinoma and the time at which it causes death is variously estimated between one and two and one-half years. Two years is the most common estimate. Naturally, such a figure is more of a guess than an estimate, for there is no real way of knowing how long a tumor has existed when it first causes symptoms or when it is first discovered. Usually such estimates are based on cases which happened to be observed early and ran prolonged courses. Uncontrolled clinical observation even over long periods tends to exaggerate the importance of these cases. The impression induced by their prolonged stay on the ward is deeper than that made by the moribund patient who is hospitalized and dies the

next day. There are numerous instances of both types in this series, and the average duration of life from the onset of notable symptoms was from six months to one year, depending on the type of tumor. There are so many factors which influence this duration, such as the age and condition of the patient, the location of the tumor, the type and severity of the accompanying infection, the location of metastases and so on, as well as the actual rate of growth and the invasive powers of the tumor, that it is difficult to evaluate its significance. The same multiplicity of factors acts in the production of symptoms. A peripheral tumor may not cause symptoms until it metastasizes, causes a pleural effusion, or grows to a large size. On the other hand, it may cause hemoptysis or chest pain early in its course, while only a small nodule. After all, we are not interested in how long the patient lives after he becomes sick except to provide ourselves with data for prognosis, but we are interested in knowing how extensive the average tumor is when it produces symptoms. For if they occur early, there is every reason to believe that surgical excision will be curative.

Jackson[5] has stated: "In a few instances the biopsy has been done so early that there has been no recurrence of the growth; it was adequately removed at the diagnostic bronchoscopy." Certainly these patients must have had symptoms warranting bronchoscopy and just as certainly these must have been early symptoms. In this series there are a number of cases with durations exceeding two years, all of which had symptoms from the beginning, and there are others in whom small, isolated tumors were disclosed although there had existed a considerable period of symptomatology (Fig. 8). Mason has stated: "But it is unfortunately probable that quite a number of cases seek medical advice, and are even admitted to the hospital in an operable state, but owing, perhaps, to procrastination or to doubt as to the efficacy of surgery, they reach the surgeon either too late, or not at all." (Fig. 8, *F* and *FF*.)

In cases such as those presented in Fig. 8, it is possible that cures might have been accomplished if surgery had been performed at the time of the first radiograph; and it is highly probable that surgery would have been curative had it been performed shortly after the onset of symptoms. The cause for such errors lies in too light a regard for time and the failure to apply rapidly all the available diagnostic measures, including surgical exploration.

Somewhat from this study, but more so from personal observations, I have come to the conclusion that symptoms tend to occur early in bronchiogenic carcinoma, and that those patients who have no pulmonary complaints until the tumor is hopelessly advanced or who feel well until metastases occur are exceptions to the rule. Physical examination, bronchoscopy, and even the posteroanterior radiograph may be negative at the onset of symptoms, but special radiographic studies

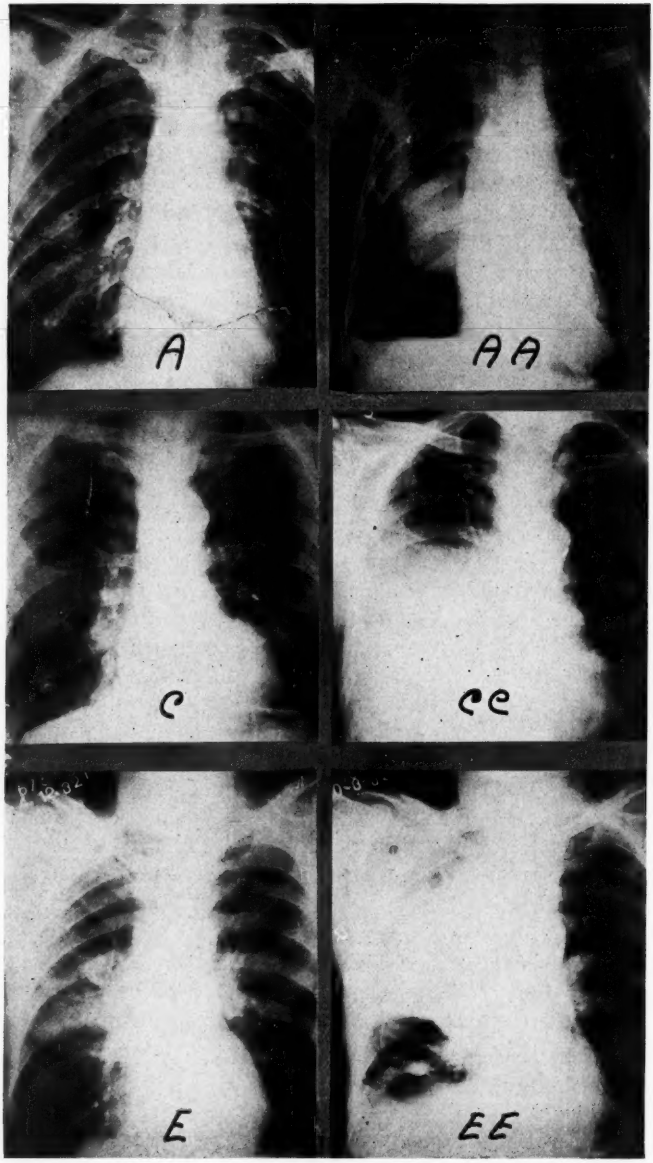
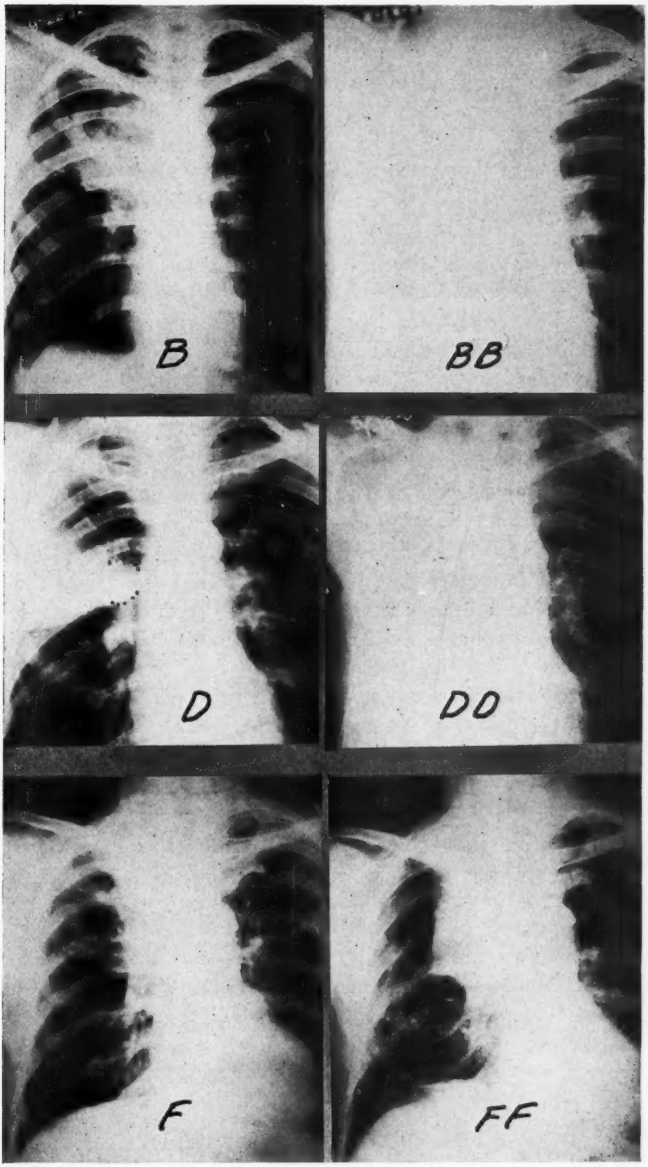


Fig. 8.—Examples of early symptomatology. *A*, This patient had visited the dispensary and complained of cough and chest pain for one month. Radiograph *A* was taken, and no follow-up was made until admission three years and four months later (*AA*). During this time pain, cough, hemoptysis, and weight loss had been progressive. *AA* was taken after aspiration of fluid and institution of air. Death occurred five months after admission. Autopsy showed adenocarcinoma.

B, The patient had had all the usual symptoms of bronchial carcinoma for two months (*B*); four years later, *BB*. Autopsy showed small-cell carcinoma (Fig. 1*B*).

C, Cough and chest pain had been present for eight months when this radiograph was taken. There is a small, irregular mass in the lower right hilus. *CC* was taken almost one year later. Autopsy revealed small-cell carcinoma of the right main bronchus.

(*Continued on next page.*)



D, The patient had had typical symptoms of bronchiogenic carcinoma for seven months. Radiograph shows a faint but regular mass adjacent to the mediastinum. The fan-shaped shadow represents atelectasis in the apex of the lower lobe. *DD* was made five months later. Autopsy showed adenocarcinoma of the right lower lobe.

E, Radiograph, taken seven months after onset of symptoms, shows an irregular, enlarged hilar shadow and a small dense mass bearing a cavity. *EE* was taken six months later (pneumothorax present). Autopsy revealed squamous-cell carcinoma arising in the right upper lobe bronchus.

F, Radiograph taken ten weeks after the onset of chest pain and cough. The patient consulted a physician two weeks after onset. Exploration was not performed until three months after *F* was made. *FF* was taken with pneumothorax just preceding exploration. An inoperable squamous tumor arising in the right upper lobe was found.[3]

and careful bronchography as well as other methods will reveal the cause for complaint. Total pulmonectomy is the way to remove it.

SURGICAL DIFFERENTIATION

The separation of the three essential types of bronchiogenic carcinoma as outlined above has led to certain conclusions in regard to surgical treatment which, in brief, are as follows:

Small-Cell Carcinoma.—Because of its central location, rapid growth, and potent invasive and metastatic powers, there is little hope that many cases will ever be cured by excision. However, those tumors arising in secondary bronchi which are diagnosed early may be completely removed by pulmonectomy. The presence of a large mediastinal mass, esophageal deformity, and vocal cord or diaphragmatic paralysis are considered contraindications to exploration. The same is true of certain bronchoscopic findings, such as: tumor within 2 cm. of the carina; enlarged, hard paratracheal lymph nodes; and widening of the bifurcation, with fixation of the carina.

Adenocarcinoma.—Those tumors arising in the periphery of the lung are most favorable for excision, but are inaccessible for tissue examination. In peripheral tumors aspiration biopsy under fluoroscopic control may frequently provide a histologic diagnosis. However, it is not a harmless procedure; the chances of disseminating the tumor or producing air embolus are good. It should not be attempted in early tumors within the hilus or if the possibility of lung abscess exists. The delay incurred by repeated attempts to obtain a biopsy by simple methods is probably more harmful than exploratory thoracotomy. Distant metastases, secondary nodules in the lung, pleural fluid containing tumor cells, and bronchoscopic evidence of mediastinal invasion contraindicate surgery.

Squamous-Cell Carcinoma.—This type of tumor is undoubtedly the best suited for surgical removal. Its frequent origin in secondary bronchi, relatively slow growth, and mild metastatic tendencies favor the possibility of complete removal. Those tumors arising in the lower lobe bronchi are within reach of the bronchoscope early, and are so located that wide resection is feasible. After they have extended up to within 2 cm. of the carina, in all probability mediastinal invasion is present despite the fact that there may be no indication of its existence. Invasion is most apt to occur in the apex of the pulmonary ligament about the inferior pulmonary vein. In like manner, the upper lobe tumors invade the hilum, encasing the pulmonary artery with tumor and frequently involving the mediastinal pleura. Although such extensions occur late in both lower and upper lobe tumors, histological diagnosis in the latter is difficult before the tumor extends into the main bronchus; only exploration will yield material for biopsy. Such exploration should not be delayed. Horner's syndrome, brachial plexus

disturbances, vocal cord or diaphragmatic paralysis, extensive rib destruction, and extreme bronchial fixation are considered contraindications to exploration.

Although some of the above conditions might not always prevent removal of the entire gross tumor, it is felt that in such instances the chances of adequate resection are too remote and that pulmonectomy should be reserved for those patients in whom there is reasonable hope for cure and in whom the removal of one lung will not result in useless, hopeless invalidism.

CONCLUSIONS

Pathologically and clinically, small-cell carcinoma, adenocarcinoma, and squamous-cell carcinoma are three fundamental types of bronchiogenic cancer.

The differences of these types early in the course of the disease sometimes permit their distinction by combined clinical, radiologic, and bronchoscopic investigations. Late in the disease this is true in approximately 60 per cent of cases.

Bronchoscopy will be negative in 40 to 50 per cent of cases if performed at the onset of symptoms. When negative, it should be supplemented by other biologic, endoscopic, and radiographic diagnostic methods until the cause for symptoms is known.

The impression that clinical symptoms tend to occur early, when the tumor is in an operable state, has been gained from this study. Therefore, it is felt that if diagnosis is made early and there is the proper selection of operative material, surgical treatment will gain a respectable position in therapeusis.

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DISCUSSION

DR. W. E. BURNETT, Philadelphia.—This excellent paper was most interesting and convincing. I had the opportunity of seeing it before this meeting, when Dr. Gebauer sent it in for examination. I am very pleased to hear that it was awarded the prize for excellence. I think this award is justly deserved, and I am sure you who have just heard the paper will all agree. It was so logical and convincing that it made one fear the obvious and resort to his own files to see how closely he could check up.

I have a few examples of cases drawn from that group. I might say at this time that in the last five years we have had 102 cases under observation in the Temple University Hospital, most of which were referred from the Jackson Clinic. Of these, we have been able to explore in about thirty-four patients in whom we found no evidence of distant metastasis. Of the thirty-four, pneumonectomy for carcinoma has been done on twelve cases.

Some of these cases are the ones I should like to present now to indicate our attempts to apply Dr. Gebauer's classification, realizing, of course, that we were not well instructed in his thought and had very little time in which to study the paper and slides to acquaint ourselves thoroughly with his standards.

(Slide) This first case, as classified by Dr. Gebauer's criteria, would be called a squamous-cell, and proved to be so on biopsy.

(Slide) This was the specimen removed at operation, showing the location of the tumor extremely high, so high that bronchoscopically it was questionable whether this tumor was removable. Having removed it at the location you see there, we realized we were very close to the tumor so we took off an additional, in fact, the last, centimeter of bronchus, and trimmed the trachea down, tapering it to the other side and obtaining a good closure by Rienhoff's method. The pathologists found no tumor in the additional bronchial segment. This man made an uneventful recovery.

(Slide) This shows the bronchus open to reveal the high location of this tumor and its type of contracture.

(Slide) This is postoperative by four months, and the subsequent one nine months later.

Here is the film of a patient about whom there was some question in my mind. I felt this might be interpreted by Dr. Gebauer's standards as adenocarcinoma, but there is a suggestion of cavitation in it. I showed it to Dr. Gebauer a little while ago and he said, "Yes, that is squamous." And so it was microscopically.

(Slide) This man also had a pneumonectomy, and this is a specimen showing the tumor in the lingula of the upper lobe, as a fairly well-circumscribed affair. (Slide) It surrounded the whole bronchus and contracted it down to complete closure. This is the mediastinal side of that same lung, which showed no glandular involvement. This man also made a good postoperative recovery.

(Slide) The next to the last patient for demonstration was one of the earliest cases we had. This small tumor is a little difficult to find, but can be seen to the left of the cardiac shadow, and on the lateral film in here. This was reached by needle biopsy, because bronchoscopy could not visualize it. This brings to mind the fact that routinely all methods are utilized and bronchoscopic negatives do not mean that we give up the search, of course.

(Slide) This lung was removed and corresponds entirely to the x-ray view. This was a small-cell carcinoma, as Dr. Gebauer called it when I checked him up a few minutes ago.

This is a patient with blockade of the lower and middle lobes on the right, which was biopsied and found to be an adenoma, according to Dr. Konzelmann. Because it was irremovable and because the patient had continuous symptoms of infection beyond the blockade, the lung was removed. This slide shows how large this tumor was. It also fungated through the bronchus, as did some of the adenocarcinomas described by Dr. Gebauer. This patient also made a good recovery and has recently been delivered of a nice child.

In brief then, let us say that we went over the last twenty-two cases of patients who had been explored, trying as best we could to apply Dr. Gebauer's standards, and we were able clinically to classify accurately about 65 per cent of the cases. We were more accurate in squamous than any other type, and I believe that corresponds to Dr. Gebauer's figures. I realize we were not applying his criteria as well as he would and possibly he could have called a higher percentage. It seems an excellent idea to be able to anticipate the histology of lung tumors from their clinical behavior. Calling our attention to group features such as these is a great contribution to our present literature.

DR. EVARTS A. GRAHAM, St. Louis.—Mr. President, I have so much I would like to say on this subject that I hope you will hold me rigidly to time and call me down.

I am always pleased when anybody attempts to simplify classifications, and I congratulate Dr. Gebauer for the attempt. My own feeling, however, is that he has not gone far enough, and I would also make one or two other points about his presentation; and, if there is time remaining, I would like to take the opportunity to show a few slides that concern what I think are important contributions to our pathologic conception.

Now, classifications are of value only if they enable us to have a better understanding of what the situation is all about. I am sorry that I will have to speak rather abruptly, because I want to get over a good deal of material.

I find it difficult—in fact, I find it impossible—to separate rigidly groups of small-cell carcinoma from adenocarcinoma. There are many tumors in which one finds a typical structure of adenocarcinoma alongside typical structures of what would sometimes be called small-cell carcinomas. It depends, therefore, upon what part of the tumor one selects from which to remove the tissue for examination.

Now, I have no hesitation whatever in agreeing fully with Dr. Gebauer on the idea that the squamous-cell carcinoma is a distinct type. That apparently comes from a metaplasia of the cylindrical epithelium, or at least from the basement layer of the epithelium. Moreover, its clinical characteristics readily set it apart from the other tumors. Its great predominance in men, its usual occurrence at a later age period, and other features are so well known that in 90 per cent or more of such cases it has been possible for one who has had a large experience to suspect that the lesion is probably a squamous-cell tumor if a bronchiogenic carcinoma seems probable in the presence of the various features just mentioned.

Then we come to a consideration of the origin of the other two classes which he has enumerated, and I think it is important to think of classifications as bearing on origin. I will say that this is a subject which Dr. Womack and I have been interested in for many years, six or seven years. We have examined a great many specimens carefully, and it is our opinion, for which I think we have a considerable amount of evidence, that the so-called small-cell carcinomas probably all come from a remnant of a bronchial bud which has been carried over from fetal life, but that, in the second place, probably all adenocarcinomas likewise come from the same origin, although there may be a few exceptions now and then which have an independent origin.

The importance of this conception, in my opinion, is that these remnants of the fetal buds are also the sources of the so-called bronchial adenomas. In our opinion, therefore—as I say, I cannot develop the line of thought in a few minutes—all bronchial adenomas are potentially malignant. It is, therefore, with jeopardy that one undertakes local removal of a bronchial adenoma. He may get away with it successfully occasionally and cure the patient of the trouble, but these tumors must be regarded, in our opinion, as potentially malignant.

Also these tumors have many characteristics identical with the mixed tumors which we see in the salivary glands. They are so nearly identical that oftentimes it is impossible to tell microscopically whether one is dealing with a mixed tumor of the bronchus or a mixed tumor of the parotid gland or of the submaxillary gland. We have submitted sections to many competent pathologists who are often unable to tell the source of the tumor, except that it is a mixed tumor. They often contain cartilage, sometimes pieces of bone, and so on.

These adenomas frequently resemble normal fetal tissue so closely that again it is impossible to distinguish between them. Normally, during fetal life, many bronchial buds are formed. All but about five of these, under normal circumstances, are supposed to atrophy and disappear, that is, in the human being. In some animals in which there are additional lobes, more remain. If one of these buds fails to

atrophy for some reason, it may remain latent for a great many years as typical fetal tissue indistinguishable from normal fetal tissue, and then because of some reason which is not clearly understood, it may begin to grow; and if it grows sufficiently, it will develop invasive qualities and become a malignant tumor.

Now, if there are a few minutes remaining, I would like to show a few slides.

I would like to say that anyone who is particularly interested in these views about which I am talking can find them more extensively developed in an article by Dr. Womack and myself in the *Archives of Pathology*, July, 1938.

(Slide) Here is one of these tumors which I would say exactly resembles the small-cell carcinoma grossly that Dr. Gebauer has mentioned. It also is identical with the structure which many people speak of as a bronchial adenoma.

(Slide) Here is a section through this tumor. You will see cartilage in this region, and here inside the cartilage are small areas of bone, and here is a larger area of bone. Around here, at the periphery, you will see what ordinarily might be designated as a small-cell carcinoma.

(Slide) Here is a high-power magnification of that part of the tissue.

(Slide) There is the lung removed. This was the lung of a woman 52 years of age, who had a tumor obstructing the bronchus at this point.

(Slide) I will call your attention to this microscopic slide here, and I would like to have you bear this in mind very closely. I will tell you that several competent pathologists called this an adenocarcinoma. Please bear this in mind.

(Slide) This is not another section of the tumor, but this is a section through a bronchial bud in a normal human fetus of sixteen weeks. Note the close similarity to the appearance of the tissue just shown.

(Slide) Here is a high-power magnification of this woman's tumor. Please keep this in mind.

(Slide) Here is a high-power magnification of the normal fetal lung of sixteen weeks, the low power of which you just saw. It is impossible to differentiate between them.

(Slide) Here is another one of these tumors. Now these tumors are frequently associated with congenital malformations. This occurred in a young man 17 years of age. He had no fissures, no lobules in the lung. A total pneumonectomy was performed.

(Slide) Here is a sample from one field. Shall we call it a small-cell carcinoma? Yes, if you wish. We prefer to think of these, however, as mixed tumors, because we think it is a more comprehensive term.

(Slide) Is it malignant? Well, you see a metastasis in the blood vessel. As a matter of fact, this young man survived operation, but a year later he developed evidences of cerebral metastasis, and I do not know whether or not he is still living.

(Slide) Here is another one of these tumors which we think of as mixed tumors, potentially malignant bronchial adenomas, if you will.

You will note a large number of accessory bronchi. As a matter of fact, there were seventeen different bronchi uniting this lung to the trachea, again an evidence perhaps of fetal abnormality which I think would tend to support the general idea. You can imagine also the consternation in removing this lung with constantly finding new small bronchial detachments.

(Slide) Here is a section of that tumor. What will we call it? Small-cell tumor or adenocarcinoma? What do you want to call it? I prefer to call it a mixed tumor of fetal origin in one of these fetal buds. That it is a malignant tumor is very evident from the invasive quality of the capsule which you see.

I am sorry I cannot go on any further.

DR. PAUL C. SAMSON, Oakland, Calif.—I had things all clear in my mind until Dr. Graham got up, and now I find myself confused again. On the other hand, I think that, by and large, the type of tumor Dr. Gebauer was talking about was not the type of tumor Dr. Graham was showing.

I might say, in preface, that some seven years ago I was working in Dr. Weller's laboratory, the pathologic laboratory at Michigan, and became interested in the autopsy studies of a large number of bronchiogenic carcinomas. It is with some pleasure that I hear some of my early views at least partially substantiated by Dr. Gebauer's paper.

In that group, about forty of which were studied personally and about sixty of which were taken from literature, we attempted to see whether there was any correlation between cell types—and I speak now of the three cell types which I still think are, in most cases, a pretty good differentiation; that is, adenocarcinoma, squamous-cell carcinoma, and the small round-cell carcinoma—and by means of mathematical formula, which is called the coefficient of correlation, we attempted to see whether those carcinomas of definite cell type tended to metastasize differently. The coefficient of correlation was picked instead of simple percentages, because each figure then gave us the tendency of a tumor to metastasize not only in relation to that particular cell type but in relation to the other cell types by comparison.

In brief, our findings were that the squamous-cell carcinomas—and this is on total autopsy material again, and not on clinical material—tended to metastasize late, if at all. They were locally invasive, involving adjacent mediastinal structures, pericardium, and so forth, really more direct extension than metastasis. Lymph node metastases, particularly distant lymph node metastases, were very rare. Metastases presumably of hematogenous origin, such as brain, kidneys, adrenals, and so forth, were rare.

The adenocarcinoma showed a tendency to metastasize widely, not only by lymph flow, but also hematogenously, so in the series of adenocarcinoma there were many metastases to the brain, kidneys, and so forth, and of course, many to the main lymph node cells of the body.

The small round-cell carcinoma, which many people in the past called sarcoma, showed a tendency to metastasize predominantly by lymph node involvement, with very little evidence in most of the cases of distant blood stream metastasis.

As a clinical application, of course, one can give a better prognosis prior to operation if a squamous-cell carcinoma is found.

Just in brief then, of six recent cases of carcinoma of the lung which have come to operation, four of them were of the squamous-cell origin, three having histories of nearly one year in duration, all operated upon, and none showing lymph node metastasis. Two were adenocarcinomas. I saw one very early adenocarcinoma that was operated upon within six weeks after the first symptom, and a small distal tumor showed microscopic lymph node metastasis. The sixth case, also adenocarcinoma of four months' duration, showed extensive metastasis to lymph nodes. The lung was removed, chiefly because it was a source of a great deal of infection. He survived eight months and died of generalized carcinomatosis.

I enjoyed this paper, and thank you for the privilege of discussing it further.

DR. ALFRED GOLDMAN, San Francisco.—First of all, let me express my appreciation of Dr. Gebauer's scholarly presentation of this subject. This question of the malignancy of bronchial adenomas and mixed tumors has interested us a great deal. We have had seventeen cases in our clinic and have reviewed the histology and histories of approximately fifty cases of adenoma seen in different parts of the country. So far, there has been but one in which metastasis to a lymph node was demonstrated. This case was one of Dr. Churchill's, and the tumor had no relation to a large bronchus. Dr. Castleman demonstrated the lone metastasis in an adjacent mediastinal lymph node. On the other hand, we collected fifteen cases (four from

our own clinic) in which the duration of the disease was more than fifteen years, without evident metastases. It seems to us, therefore, that the tumor which we recognize as bronchial adenoma is neither potentially malignant nor distantly metastasizing. We know of no case in which distant metastases have occurred.

Because of this, we fail to see why Dr. Graham should feel that this particular tumor is potentially malignant, unless its qualities, despite the absence of metastases, are considered sufficient to place it in that class.

We recognize, of course, that these tumors do grow beyond the bronchial wall and that they do produce pressure atrophy. However, in some which have reached the size of an orange, have destroyed a whole lobe, and have had a proved duration of more than twenty years, no metastases to lymph nodes occurred.

DR. GEBAUER.—I wish to thank Dr. Burnett. One case he showed of a small tumor arising in the left lower lobe, he also showed me before the meeting, and I thought it could be a benign adenoma, a primary adenocarcinoma or a primary small-cell carcinoma, or secondary tumor.

I agree with Dr. Graham that there is some confusion in differentiating between adenocarcinomas, bronchial adenomas, mixed tumors, and small-cell carcinomas. The criteria of the pathologist regarding malignancy and the criteria of most surgeons regarding malignancy are histologic, but the proof of malignancy is not the histologic picture; it is metastasis and invasion.

The only thing that prevents me from discussing it or trying to clear up the confusion is the fact that we have not seen many benign adenomas and mixed tumors. I would be pleased to have an opportunity to see these mixed tumors and benign adenomas and the small-cell carcinomas which simulate benign adenomas. We have seen a few benign tumors in which a biopsy may be misleading. The histologic field contains all the criteria for malignancy, with mitotic figures and wild growth, invasion of blood vessels, and so forth, but in the gross specimen the tumors are sharply circumscribed, there are no lymph nodes involved, and there seems to be no invasion at the periphery of the tumor.

As I say, I think the proof of malignancy is not the histologic picture as much as the end result, and I believe that we should treat these bronchial adenomas as potential malignancies (not necessarily completely radical), regardless of the fact that in seventeen cases there was only one, as reported by Dr. Goldman, that had lymph node metastasis.

I am familiar with Dr. Samson's work, and I was pleased to find mine confirmatory.

I would like to take this time to express my sincere appreciation for the helpful criticism and guidance of Dr. S. O. Freedlander.

SURGICAL ASPECTS OF CARCINOMA OF THE ESOPHAGUS

Review of the Literature and Report of Four Cases

Alton Ochsner, M.D., and Michael DeBakey, M.D. (by invitation)
New Orleans, La.

THE relative frequency and the apparently increasing incidence of carcinoma of the esophagus and its persistent obstinacy to all forms of therapy clearly reveal its growing importance. Although this statement is true of malignant lesions of the entire esophagus, it is particularly applicable to such lesions involving the thoracic portion which comprise by far the greatest number. This fact, in addition to the almost unanimous admission of failure of all other forms of curative therapy, clearly emphasizes the surgical significance of this condition.

Whereas there is considerable variation in the incidence of carcinoma of the esophagus in different countries and in various cities of the same country, it is generally considered to comprise approximately 5 per cent of all malignant disease. Whereas Souttar[230] states that its incidence in all malignant disease is from 4 to 6 per cent, Ernst[72] believes it to be from 6 to 10 per cent. In Switzerland, Renaud[210] found that 10 per cent of all carcinomas involved the esophagus and that 16.2 per cent of males with malignant disease had carcinoma of the esophagus. It is estimated that in Europe approximately 25,000 persons die annually of this disease and that in Switzerland it ranks second among malignant diseases as a cause of death.[46, 210] At the Breslau Pathological Institute, the incidence of carcinoma of the esophagus in all carcinomas was 12.1 per cent.[223] In England and Wales the annual mortality from carcinoma of the esophagus is about 1,600.[229] At the Royal Melbourne Hospital, carcinoma of the esophagus ranked sixth in the cancer causes of death.[129] In New South Wales, during the period from 1934 to 1936 inclusive, the esophagus ranked fourth in frequency as the site of carcinoma in males; comprising 4 per cent of all cancer deaths in males, carcinoma of the esophagus accounted for 1 in 242 deaths from all causes in males[101] In the United States, Hoffman[112] found that the mortality from carcinoma of the esophagus exceeds 2,000 per year. He also observed that its incidence based on per hundred thousand population increased from 1.0 in 1915 to 1.7 in 1932. This increase is further demonstrated by the rates in San Francisco where it was found that the incidence of carcinoma of the esophagus to all malignancies was 4.4 in the period from 1920 to 1923, 5.9 from 1924 to 1927, and 6.1 from 1928 to 1931. These

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incidences in Chicago were 5.2; in Boston, 5; and in New Orleans, 2.3. According to Watson,[267] carcinoma of the esophagus accounts for 3.5 per cent of all malignant deaths in New York City and 2.5 per cent of all admissions to the Memorial Hospital.[266] Ehrlich[68] found that it comprised 1.8 per cent of all admissions to the New York Cancer Institute. At the Philadelphia General Hospital carcinoma of the esophagus constituted 0.1 per cent of all admissions[167] and 5 per cent of all post-mortem malignancies.[47] At the Peter Bent Brigham Hospital, it comprised 0.14 per cent of all admissions.[83] Thus, from these figures it may be readily observed that carcinoma of the esophagus occurs with sufficient frequency to warrant serious considerations.

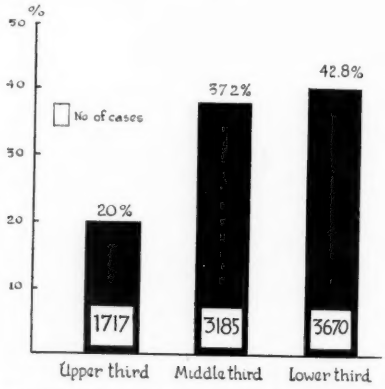

Chart I.—Graphic representation of relative incidence of site of lesion in carcinoma of the esophagus, based on 8,572 collected cases.[282]

In addition to its relatively high incidence, carcinoma of the esophagus is also of surgical significance, particularly to those interested in the thoracic field of endeavor, because of the preponderance of involvement of this segment of the esophagus. In a collected series of 1,670 cases of carcinoma of the esophagus, Janeway and Green[122] found that almost 85 per cent of the lesions occurred in the middle and lower thirds of the esophagus. Similarly Ridder[136] found this to be 73 per cent, and Lerche,[149] 75 per cent. In a collected series of 8,572 cases,[282] this incidence was 80 per cent (Chart I). Thus, approximately four-fifths of the lesions in carcinoma of the esophagus occur in the thoracic and abdominal portions of the esophagus. This fact clearly emphasizes the therapeutic significance of this disease because these areas are the least accessible and are therefore attended with greater technical difficulties.

Aside from the technical inaccessibility of this portion of the digestive tube and the difficulty of approach, other factors have played significant roles in delaying progress toward the successful surgical management

of this tragic disease. Of these, one of the most important is the inherent anatomic characteristic of this segment of the digestive tract. The fact that the esophagus is devoid of serosal covering, a layer which is so important in gastrointestinal anastomoses and which is responsible for accurate approximation and sealing of gastrointestinal wounds, obviously increases the danger of its extirpation. This danger is enhanced

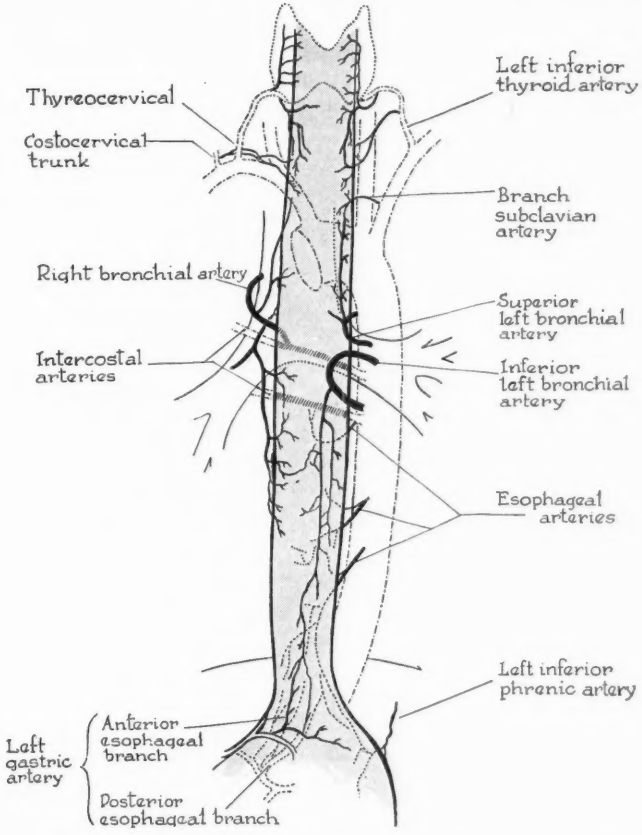

Fig. 1.—Diagrammatic representation of blood supply of esophagus (after Ohsawa, Arch. f. Jap. Chir. **10**: 605, 1933). The relative vascular paucity, particularly just above the cardia and in the area supplied by the inferior thyroid artery, may be clearly observed. The danger of vascular insufficiency following ligation of the inferior thyroid may be easily realized.

further by its relatively vascular paucity and collateral blood supply[54a, 199, 216] (Fig. 1). Moreover, insufficiency of anastomosis is favored further by its relative fixity and lack of redundancy. This traction on the suture line of anastomosis is unfortunately increased by the presence of the longitudinal musculature in the esophagus. In addition to these

inherent anatomically technical difficulties, there is the danger of tension pneumothorax consequent to pleural injury, which has been particularly emphasized by Meyer, Nather, and Ochsner,[171] who observed fatalities from such injuries following esophageal resection.

The susceptibility of the mediastinum to infection is also considered a prominent factor. The severe infections associated with operations upon the esophagus are probably due to the characteristic bacterial flora in the pharynx and in the upper digestive tract, of which the most significant are the anaerobic organisms, the spirochetes, and the fusiform bacilli of Vincent.

The greater risk attending operations upon the esophagus for malignant disease than that attending similar procedures lower in the digestive tract is probably due to the greater interference with nutrition and the consequent dehydration, hypoproteinemia, and diminished resistance in the former group of patients.

Because of these numerous difficulties and obstacles which beset the path of progress in the surgical approach to this condition, the therapeutic advances have been painfully slow and woefully inadequate. Without detracting from the admirable achievements of a few surgeons, it must be admitted that the brilliance of these isolated accomplishments was considerably enhanced by the surrounding gloom resulting from the majority of attempts. It was little wonder, therefore, that many investigators became convinced that surgery offered no hope, and placed their efforts in irradiation therapy. It was soon realized, however, that this therapeutic measure was unfortunately even less efficacious. With few exceptions, cures have rarely been reported.[283] In fact, the great majority of investigators are of the opinion that the life expectancy is not even extended. In a series of 297 cases reported by Nathanson and Welch,[191] it was found that the median life expectancy of the untreated patients was seven months; of those treated by gastrostomy, only 10.4 months; and of those treated by irradiation, 9.3 months. McCullagh[168] found that of fourteen patients treated by irradiation none survived two years. Watson[266] reported that the average life expectancies in the cases treated by gastrostomy and external irradiation, gastrostomy and internal irradiation, and gastrostomy and external and internal irradiation were 6.3, 3.7, and 3.9 months, respectively. Zuppinger[281] found that the difference in survival periods of those treated by irradiation and those not treated was 0.3 month; Cleminson and Monkhouse[48] found that the average survival period following irradiation was 5.6 months. Stone,[233] at the Memorial Hospital, New York City, states that not a single case of carcinoma of the esophagus has been cured by radium. Numerous others, on the basis of extensive experience, have expressed the opinion that irradiation therapy is futile. Even Guisez,[95-99] who has been an ardent advocate of irradiation therapy, has more recently stated that its value is

chiefly palliative. It has been definitely demonstrated, therefore, that irradiation therapy is of practically no curative value, a fact that clearly emphasizes the surgical significance of this difficult problem.

Of particular interest from a surgical standpoint is the relative malignancy of carcinoma of the esophagus. Because the condition is manifested clinically by rapidly progressive deterioration, as clearly revealed by the fact that the average survival period from the onset of symptoms is from six months to one year,[284] the lesion would seem to be characterized by rapid growth and a high degree of malignancy. The clinical evidence of high malignancy has been emphasized by Souttar[229] and Vinson.[262-264] On the other hand, Woodman,[270, 271] Wright,[272] and Jackson[119, 120] have considered the condition relatively benign as long as the tumor is confined to the esophagus. Abel[1] stated that 25 per cent of fatal cases of carcinoma of the esophagus are operable. This contention is further substantiated by a series of 1,025 cases[285] observed at autopsy, of which 418 (40.7 per cent) showed no evidence of metastases. It is logical that most, if not all, of these cases were operable even though the patient had died of the malignant lesion. Undoubtedly, had the diagnosis been made early or at least some time before death, the incidence of operability would be much higher. Obviously, the apparently high malignancy observed clinically is due in great measure to the obstructive character of the lesion involving a narrow portion of the digestive tube and resulting in early starvation. Another significant factor is the location of the tumor and its close proximity to vital structures. The possibility of extension to other viscera, such as involvement of the aorta and trachea, with perforation of either, and the possibility of regurgitation and aspiration of esophageal material, with the production of pneumonic processes, clearly demonstrate its lethal character.

Because, as previously stated, the nonsurgical methods of therapy are of little or no curative value in carcinoma of the esophagus, and because pathologically the lesion is relatively benign, being localized to the esophagus for long periods of time, surgical extirpation remains the only curative therapeutic measure. Whereas the outlook in the past following surgical extirpation of esophageal neoplasms has been very gloomy, as evidenced by the high mortality rate in these cases, at present because of the advances which have been made in thoracic surgery and in anesthesia, the prospects are considerably more optimistic.

Multivarious types of operations have been proposed and performed for the resection of esophageal carcinoma, but they can be classified logically into five groups, as follows: (1) thoracicocervical; (2) thoracicoabdominal; (3) thoracic; (4) abdominal; and (5) abdominocervical. Of these five methods, in the first three either transpleural or extrapleural approaches have been used. In the choice of a particular operative procedure in a case of carcinoma of the esophagus, there may

be the personal preference of the surgeon concerning the type of operation, but generally the location of the lesion in the esophagus will be a determining factor. For example, the abdominal approach would be used only in lesions located in the lower part of the thoracic esophagus or in the abdominal portion of the esophagus.

Billroth,[23] in 1871, first demonstrated that resection of the esophagus was feasible. His original experiments, which were successful, were performed on dogs. Although this presentation is concerned with the treatment of the thoracic and the abdominal portions of the esophagus, it is of historical interest that Czerny,[51] in 1877, was the first to extirpate successfully a carcinoma of the esophagus in the cervical portion. Following resection of the tumor, the lower end of the esophagus was brought out of the wound as an esophagostomy. The patient succumbed fifteen months later of recurrence. Mikulicz,[181] in 1884, also performed a resection of the cervical esophagus and repaired the defect by a plastic procedure. Although many attempts at resection of the thoracic esophagus had been made, the brilliant accomplishment of Torek, in 1913, was the first to be successful. His patient lived eleven years and died of pneumonia at the age of 80.

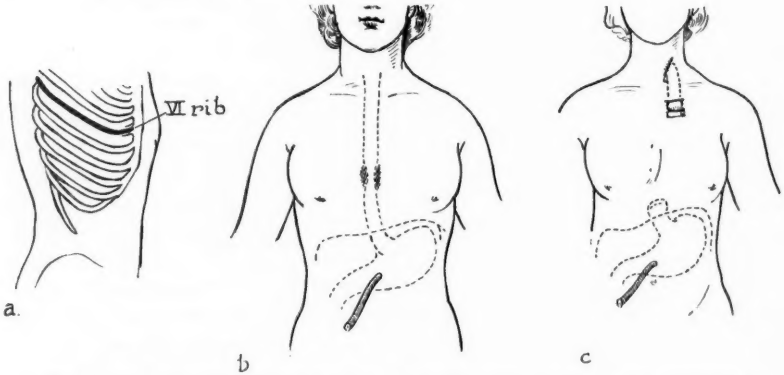

Fig. 2.—Diagrammatic illustration of thoracicocervical approach for resection of carcinoma of the esophagus. *a*, The incision is made over the right sixth rib. Whereas some surgeons prefer the right side, others prefer the left. Still others use an extrapleural approach (see text). *b*, A preliminary gastrostomy should be done before attempting the resection. *c*, After resection of the lesion, the lower end of the esophagus is inverted and the upper end is brought out through the cervical wound and then under a skin tunnel through an opening over the chest.

One of the earliest attempts to resect the thoracic esophagus in human beings was made by Faure in 1902. This operation was performed according to the thoracicocervical technique, which consists of mobilization of the esophagus through a thoracic wound, dividing the esophagus well below the tumor with closure of the lower esophageal segment, and the mobilization of the upper esophageal end, together with the tumor, out through a cervical wound on the left side (Fig. 2). Faure performed

the cervical portion of the operation first and used an extrapleural approach to the thoracic esophagus through an incision in the right hemithorax. He reported two cases in which this procedure was done; both patients died within twenty-four hours after the operation. Mickulicz, in 1904, performed a resection of the esophagus for carcinoma, using the thoracicocervical approach. Instead of simply bringing the upper end of the esophagus out through the cervical wound, he dissected a tunnel under the skin of the anterior thorax, bringing the esophagus through this tunnel for a short distance. This patient also died. Wendel, in 1910, performed a thoracicocervical resection, but modified it so that the aboral end of the esophagus was brought out to the chest wound and the oral end out of the cervical wounds. The patient died of a bilateral pneumothorax. In 1913, Barbat performed unsuccessfully a thoracicocervical resection of the esophagus, and in the same year Torek performed the first successful resection of the thoracic esophagus, using the thoracicocervical approach. As mentioned above, this patient survived the operation eleven years and was able to maintain a good state of nourishment by connecting the distal end of the proximal esophagus with the gastrostomy opening by means of a rubber tube. Since Torek's case, fifty-three additional cases have been reported in which resections have been done according to the thoracicocervical technique. Of the total number of fifty-eight cases,[286] not including the authors' forty-one (70.6 per cent) died.

The thoracicoabdominal approach consists of the performance of a thoracic operation with mobilization of the esophagus, and also an abdominal procedure either through a separate incision or by an extension of the thoracic wound. Among the earliest to propose this type of procedure was Sauerbruch,[218] who in 1905 performed experiments on cadavers which consisted of transthoracic mobilization of the lower end of the esophagus and its invagination (einstülpung) through the cardia into the stomach. At a second stage, through a laparotomy, the stomach was opened and the invaginated portion of the esophagus was removed. Apparently, Sauerbruch did not perform this procedure on a patient. Relatively recently, Ohsawa[199] reported two cases of carcinoma of the esophagus in which this operation was employed, in one of which it was successful. One of the earliest to use the thoracicoabdominal approach in a patient was Henle, whose case was reported by Tiegel, in 1909. A laparotomy was done first, and the upper half of the stomach was mobilized and severed below the tumor. The proximal opening was closed and a Murphy button placed in the lower end. A left thoracotomy was then done and the esophagus was severed above the tumor, which was removed; an esophagogastrostomy was completed with the button. The patient died of collapse of the left lung eleven hours later. A variation of this procedure was used by Wendel in 1910. Through

a left thoracotomy incision the esophagus was divided above the tumor. The upper end was brought to the outside through the thoracotomy wound and the lower end was closed. A laparotomy was then done, and the mobilized portion of the esophagus, including the tumor, was brought down and resected. The opening in the stomach was made into a gastrostomy. The patient died twenty-four hours later of collapse of the left lung. In 1910, Janeway and Green[122] reported a case of carcinoma of the esophagus in which resection was performed using the thoracicoabdominal approach. They first performed a laparotomy and completely mobilized the stomach by ligating the gastrohepatic and gastrocolic omentums. Through a thoracotomy incision the lower end of the esophagus was mobilized and the stomach partially transplanted into the pleural cavity through a radical incision in the diaphragm. The involved portion of the esophagus and almost the entire stomach were resected, and continuity of the tract was re-established by end-to-end anastomosis. Similar procedures with minor variations have been done by others.[65, 198]

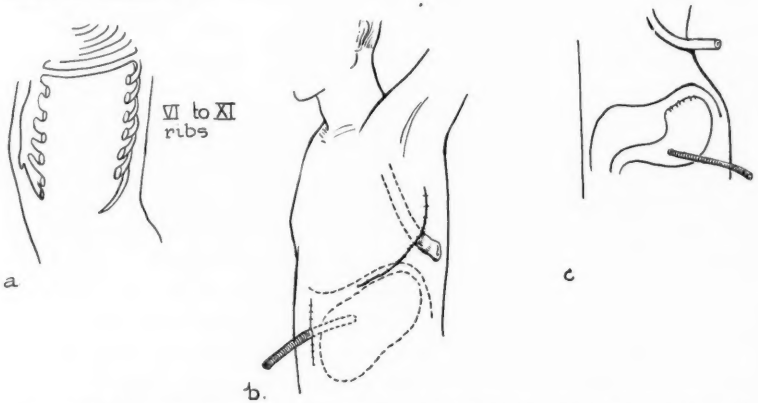

Fig. 3.—Diagrammatic illustration of thoracicoabdominal approach for resection of carcinoma of the esophagus, as suggested by Zaaijer. *a*, Thoracoplasty by subperiosteal resection of the left sixth to eleventh ribs to permit the chest wall to fall in and thus shorten the distance between the esophageal bed and skin surface. *b* and *c*, Preliminary gastrostomy having been performed at a previous stage, an incision is made beginning just below the costal margin in the mammary line and curved posteriorly and upward toward the angle of the scapula. The diaphragm is split and pleural and peritoneal cavities are entered. The tumor is resected, the lower end of the stomach closed, and the upper end of the esophagus brought out through the chest wound.

Another type of thoracicoabdominal approach for resection of the thoracic esophagus was suggested by Zaaijer[276] in 1911. His operation was done in stages (Fig. 3). As a preliminary procedure he performed a gastrostomy. Subsequently, he did an extensive thoracoplasty on the left side, with resection of the sixth to the eleventh ribs inclusive (Fig. 3*a*). This permitted the chest wall to fall in and thus shorten the distance between the esophageal bed and the skin surface (Fig. 3*c*). At a subsequent stage, a long incision was made, extending from the lower

hypochondrium in the mammary line on the left side, laterally to the posterior axillary line, and then ascending to the angle of the scapula. The thoracic and abdominal cavities were opened through this incision and the diaphragm was severed. The distal end of the esophagus, together with the cardia, was resected. The upper end of the stomach was closed blindly, and the proximal end of the esophagus brought out through the chest wound. Zaaijer's patient recovered from the operation and died of inanition three months later. With slight modifications, a similar procedure was performed by Hedblom[103] whose patient likewise recovered and lived several months, but subsequently committed suicide. In all, there have been performed sixteen esophageal resections[287] for carcinoma through the thoracicoabdominal approach, with four (25 per cent) recoveries (Chart II).

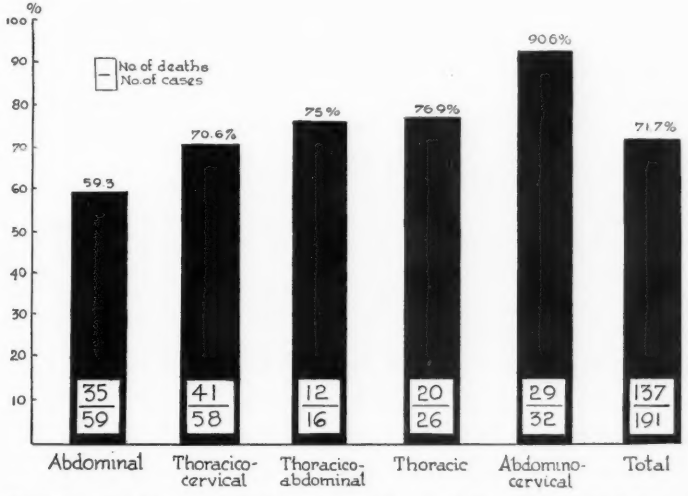

Chart II.—Graphic representation of operative mortality in 191 collected cases of carcinoma of the esophagus, not including the authors', according to type of operation performed.

The thoracic esophagus has been extirpated for carcinoma through a thoracic approach only. It is desirable to divide these cases into two large groups; those located in the upper part of the thoracic esophagus, and those in the lower part. One of the earliest to use this approach was Willy Meyer, who, in 1912, reported four cases in which a segment of the thoracic esophagus in its upper portion containing a carcinoma was resected, with blind closure of the proximal and distal ends. This was done transpleurally through a Schede incision. All patients died, although one survived twenty-four hours. In 1914, Hauch reported Kümmell's cases in which a horizontal quadrilateral flap of skin was used to place under the mobilized esophagus. In this way it was hoped that

infection of the wound would be prevented and that re-establishment of the continuity of the digestive tube could be accomplished. Three patients were operated upon, all of whom died. In 1917, Höfer and Kafler performed experiments on cadavers, using a similar technique but employing a triangular skin flap. The flap was placed beneath the mobilized esophagus, to which it was attached. At a later stage the tumor-bearing portion of the esophagus was to be removed, following which a plastic operation would be performed. A similar procedure was used by Lilienthal[153] in a successful extirpation of the mid-esophagus. The patient succumbed sixteen months later of recurrence. Orator performed a resection of the upper esophagus transthoracically in two stages by first freeing the esophagus and surrounding the mass with paraffin. At a subsequent stage, after the wound had become badly infected, the tumor-bearing portion of the esophagus was removed, with ligation of the distal and proximal ends. The patient succumbed to a phlegmon of the thoracic wall.

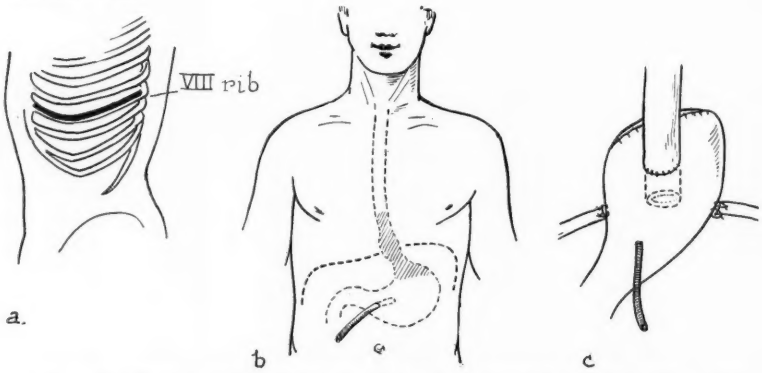

Fig. 4.—Diagrammatic illustration of the thoracic approach for resection of carcinoma of the lower end of the esophagus. *a*, Incision is usually made over the left eighth rib which is subperiosteally resected, and the pleural cavity is entered through its bed. Some surgeons prefer intercostal incisions. After entrance into the pleural cavity, the diaphragm is incised and the esophagus and stomach are mobilized. *b*, The tumor is resected, including a portion of the esophagus and stomach, as shown by the shaded area. *c*, The upper end of the stomach is closed, and the esophagogastrostomy is performed, usually by end-to-side anastomosis. The diaphragm is closed around the stomach.

Tumors at the lower end of the esophagus in the region of the cardia can be approached satisfactorily transthoracically and can be removed by the production of an artificial diaphragmatic hernia and the transdiaphragmatic mobilization of the stomach into the thorax (Fig. 4). In this way, after resection of the malignant lesion in the lower end of the esophagus, an anastomosis between the esophagus and the stomach can generally be accomplished. Biondie, in 1895, performed experiments on dogs and showed the feasibility of esophagogastrostomy following the transpleural, transphrenic resection of the distal portion of the

esophagus. Similar experiments were performed by Gosset, in 1903, on dogs and on cadavers. Gosset, Mikulicz, and Sauerbruch did further experimental work on this type of anastomosis. One of the earliest to utilize this procedure in a patient was Wendel who, in 1907, performed a resection of the lower end of the esophagus transthoracically and transphrenically, with re-establishment of the continuity of the alimentary tract by lateral anastomosis with a Murphy button. His patient died twenty-four hours later of hemorrhage. Bengolea, in 1919, performed an anastomosis over a wooden bobbin following transpleural, transphrenic resection of a carcinoma of the lower end of the esophagus. His patient survived the operation, but succumbed thirty-seven days later of empyema. Fischer, in 1926, proposed a procedure which would make the anastomosis between the esophagus and the stomach more secure. Following the closure of the proximal end of the stomach, a quadrilateral flap of the seromuscularis of the anterior wall of the stomach is made with its base distally. Near the base of the flap the mucosa is opened and the distal end of the esophagus is sutured to it. Following this, the flap is replaced, covering the distal end of the esophagus for a considerable distance. Although Fischer has never performed the operation himself, this procedure has been used by Starr[232] and Decker.[52] However, both patients died. The first successful case of this type was reported by Adams and Phemister in 1938. In sixteen cases the lower end of the esophagus has been resected transthoracically; of these, only five patients have recovered. Twenty-six carcinomas[288] of the esophagus have been resected transthoracically; of these, only six patients have recovered (Chart II). However, it is significant that of six cases reported since 1938, five have survived the operation.[289]

In all of the three above-described thoracic procedures, namely, the thoracicocervical, the thoracicoabdominal, and the thoracic, it is possible to perform the resection either transpleurally or extrapleurally. There has been considerable controversy among authorities concerning the value and the disadvantages of each. Nassilov, in 1888, performed experiments on cadavers, mobilizing the thoracic esophagus extrapleurally. He did this through a paravertebral incision, with resection of segments of the third to the sixth ribs. Quénu and Hartmann, in 1891, and Potârca, in 1894, similarly demonstrated this approach on the cadaver and in dogs. Bryant, in cadaveric experiments, showed that extrapleural mobilization of the esophagus could be used through a quadrilateral flap incision. In 1895, Rehn first mobilized a human esophagus extrapleurally. This procedure was done in two cases, one for carcinoma which was inoperable and one for a stricture. Faure, in 1903, was the first to extirpate a carcinoma of the thoracic esophagus extrapleurally. The

procedure was done in two cases, but both of the patients died. In 1895, Biondie demonstrated in animals the possibility of resection of the esophagus transpleurally. In the same year, Llobet performed a transpleural operation for a diaphragmatic hernia in a human being. This was apparently one of the earliest deliberate transpleural operations done in a human being. Llobet emphasized the safety of the transpleural approach and the fact that the reported dangers had been greatly exaggerated.

There are many arguments in favor of and against the extrapleural and transpleural procedures. The proponents of the extrapleural approach maintain that it is preferable because of the supposed susceptibility of the pleura to infection. Also, theoretically, there should be less disturbance of respiration because the negative pressure within the pleural cavity is maintained. On the other hand, the extrapleural procedure has many disadvantages. It increases the technical difficulties because exposure is usually inadequate and injury to the pleura almost invariably occurs. As emphasized by Tuffier, the operative wound is definitely limited, making the operation much more difficult and less satisfactory to perform. The danger, therefore, of infection and recurrence is greatly augmented. Based upon their experience with both procedures, the authors are thoroughly convinced that the intrapleural approach is not only much easier, but also is as safe or safer, primarily because one can have better control of the operative field.

In addition to those who have advocated the extrapleural approach for lesions located in the midthoracic esophagus, some have also proposed the extrapleural approach of the lower esophagus in performing the thoracicoabdominal type of operation. Sencert, in 1904, advocated mobilization of the lower thoracic esophagus extrapleurally through a paravertebral incision. The pleura was mobilized from the diaphragm and the posterior and lateral parietes, following which the diaphragm was incised. The stomach was mobilized through the diaphragmatic opening and thus brought into the thoracic cavity. Grégoire and Lilienthal, in 1923, advocated the extrapleural approach for carcinoma of the lower portion of the thoracic esophagus.

There has also been some controversy among authorities concerning the best side to approach a lesion of the thoracic esophagus. Although the esophagus is located on the left, its approach from the left side is attended with some difficulty, because it is bounded on the left by the aorta. Approach to the esophagus on the right side is made difficult by the vena azygos major passing over the esophagus in its upper portion to empty into the superior vena cava. Whereas some[290] are of the opinion that the left side is preferable, others[291] believe the approach is better from the right. Baumgartner was of the opinion that lesions located at the level of the aortic arch are best approached from the right,

whereas those below this level are best approached from the left. A similar opinion was expressed by Abel. As a result of our experience, we are convinced that tumors in the upper part of the thorax are best approached from the right side. It is far easier to mobilize the esophagus and to ligate the esophageal arteries arising from the arch of the aorta when approached from the right than from the left side. Only in those instances in which the tumor is located in the lower part of the thoracic esophagus is the approach easier from the left side. It should be emphasized that in approaching the esophagus from the right it is not only desirable, but almost necessary, to transfix, doubly ligate, and divide the vena azygos major, which can be done with impunity, as has been demonstrated in our cases of esophageal resection and in our cases of right-sided total pneumonectomies.[195]

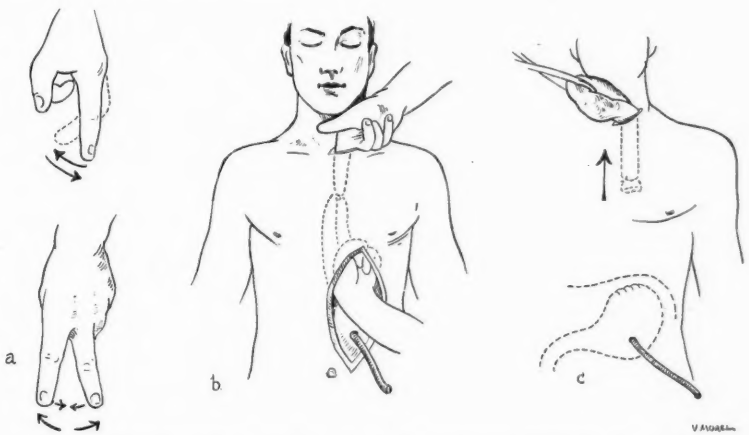

Fig. 5.—Diagrammatic illustration of abdominocervical approach (tunneling) for resection of carcinoma of the esophagus. A preliminary gastrostomy is made, and through the abdominal and cervical incisions the esophagus is bluntly dissected free with the fingers, as shown in *a* and *b*. The esophagus is then severed, the lower end inverted into the stomach, the esophagus brought out through the cervical wound, and the excess resected, as shown in *c*.

Carcinoma of the thoracic esophagus at various levels has been removed by the abdominocervical approach which consists of mobilizing the esophagus from the cervical and abdominal ends by bluntly freeing the esophagus from its attachments, usually by means of the fingers introduced into the cervical wound and in the abdominal wound (Fig. 5). In a number of instances, special instruments, such as a ring attached to a wire into which the esophagus is threaded to permit isolation of the esophagus similar to the stripping of a vein with the Mayo vein stripper, have been advocated. This was first suggested by Denk. Likewise, the introduction of a sound into the lumen of the esophagus and the fixation at the opposite end with an attempt either to invaginate or

plicate the esophagus as is accomplished by the Babcock vein stripper have been tried.[102] Levy (1898) performed extensive experimental investigations and showed that in the animals, at least, it is possible to invaginate the esophagus successfully. He freed the esophagus in the cervical and lower thoracic areas and passed a wire through an esophageal fistula in the neck down to the abdominal portion. Following division of the esophagus in its lower portion, the esophagus was tied to the wire, and the esophagus was removed by invaginating the esophagus in itself. Although Levy deserves credit for his pioneer work, he, personally, never did perform the operation upon patients. Ach was the first to apply this principle in human beings. He had four patients, and all of them died. Denk, using the ring stripper, operated upon two patients, both of whom died. Kümmell, Jr., in 1922, mobilized the esophagus throughout by bluntly freeing it with the fingers introduced from the cervical and abdominal wounds, respectively. After freeing the esophagus, he brought it out through the cervical region, thus transplanting the stomach into the esophageal bed. Following this, the diseased portion of the esophagus was resected and a re-establishment of the continuity accomplished by an end-to-end esophageal gastric anastomosis. This procedure was done in two patients, both of whom died. In all, thirty-two cases in which the "tunneling" procedure has been used have been reported,[292] of which only three survived (Chart II). These were the patients of Turner (1933), Fischer (1937), and Bernhard (1939). Whereas Kümmell attempted to re-establish the continuity of the alimentary tube by mobilization of the stomach into the esophageal bed, most of the men using this procedure were content with resecting the thoracic portion of the esophagus and leaving the patient with a cervical esophageal fistula and a gastrostomy. This procedure, which appears to have many advantages because the thorax is not opened widely, is open to serious criticism. It is obviously the least surgical of all of the approaches used in resection of the thoracic esophagus. The great danger of tearing the pleura is manifest by the report of Meyer, Nather, and Ochsner, who emphasized the danger of a tension pneumothorax following this type of procedure, which they observed in cases operated upon by Clairmont. The blind tearing out of the esophagus, without the possibility of controlling hemorrhage, and the impossibility of freeing the tumor adequately, particularly if it is attached to the surrounding structures, preclude the possibility of a complete extirpation. Even Levy, who was an ardent advocate of the procedure, concluded that it was not feasible in man because of the tearing of the external muscle layers in performing the operation. The possibility of perforation of the tumor is particularly great in those cases in which the esophageal wall has been largely replaced by neoplasm.

In the low thoracic esophageal carcinomas and in carcinomas involving the abdominal portion of the esophagus, the abdominal approach can be used and is frequently the method of choice (Fig. 6). One of the earliest to use this approach in a patient was Voelcker, who, in 1908, performed a resection of the lower end of the esophagus through an abdominal incision. The patient had an esophagogastrostomy and recovered. In 1905, Sauerbruch, experimenting on dogs, suggested an invagination of the lower end of the esophagus into the stomach (einstülpung) and later excision of the tumor within the stomach. Although Sauerbruch never carried out this procedure on human beings, it has been used by Voelcker and Ohsawa. The former used it in one case, and the latter in two.

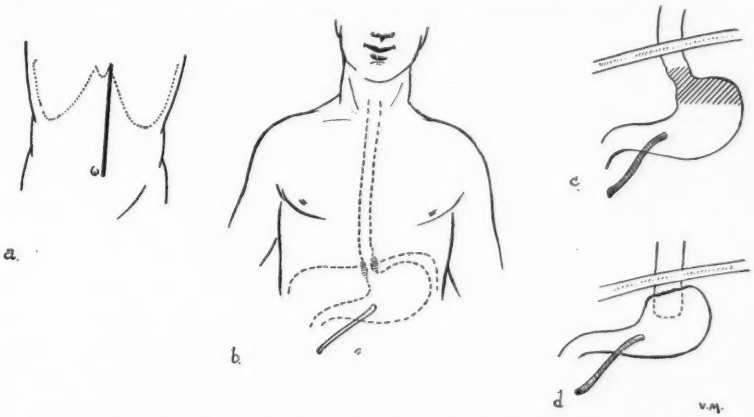

Fig. 6.—Diagrammatic illustration of abdominal approach for resection of carcinoma of the lower end of the esophagus. *a*, The incision may be paramedian, left paracostal, or similar to that described by Marwedel.[166] A gastrostomy or jejunostomy may be employed, although some believe this is not necessary. The upper part of the stomach and the lower end of the esophagus are mobilized and the tumor is resected, including a part of the stomach and esophagus, as shown by the shaded area in *c*. Following this, an esophagogastrostomy is done, usually as an end-to-side anastomosis *d*.

Two of the three patients succumbed, one of Ohsawa's cases and the patient of Voelcker. Whereas in the majority of instances an attempt was made to re-establish the continuity of the digestive tube by means of sutures, either end-to-end between the esophagus and the stomach,[102, 199] or by end-to-side anastomosis between the end of the stomach and the anterior wall of the stomach[65, 199] or by the use of the Murphy button,[137, 265] Kümmell, after resection of the involved portion of the lower esophagus, left a tube in the esophageal stump and a tube in the gastric stump, bringing both tubes to the outside. In his first case, which was successful, he subsequently used a T tube connecting the esophageal and gastric ends. This patient lived and was in good condition for a year and finally died of recurrence. In addition to this successful case reported by Kümmell, Hauch reported six additional cases from Küm-

mell's clinic in which this same procedure of leaving tubes in the esophageal and gastric openings was done. None of these recovered.

The end-to-end esophagogastrostomy was advocated and performed by Voelcker, Lotheissen, and Hauch. As mentioned above, the Murphy button has been used in some instances.[137, 265] Bircher[25] performed the anastomosis by inverting the esophagus into the opening of the stomach as is done in the Stamm method of gastrostomy. A similar technique was subsequently described by Lilienthal.[157] End-to-side anastomosis was done by Ohsawa[199] and Eggers.[65] In all, there have been reported fifty-nine cases of esophageal resection by the abdominal approach,[293] with twenty-four recoveries (Chart II).

The incisions employed for the various operations have been manifold. In those instances in which the approach has been through the cervical region, almost without exception the incision and approach have been the same, i.e., along the lower anterior border of the left sternocleidomastoid muscles. In those patients in whom the left lateral lobe of the thyroid is large, it is mobilized forward so that the esophagus can be freed. Although mobilization of the thyroid is important, it is imperative that the inferior thyroid artery not be ligated or injured, because in so doing, the vascularity of the mobilized esophagus may be interfered with, resulting in loss of a considerable portion of the esophagus (Fig. 1). In those cases in which a thoracicocervical approach is used, we are of the opinion that the thoracic procedure should be done first. However, before closing the thoracic wound, the cervical portion of the operation should be started. This will facilitate removal of the upper portion of the esophagus and save time because the cervical portion of the operation can be completed while the thoracic wound is being closed.

The incisions employed for the thoracic approach are manifold. Many types of incisions, including extensive paravertebral flap incisions, have been used. We are of the opinion, however, that in both the thoracicocervical and the thoracic approaches either a long intercostal incision, or the resection of a single rib, with possible paravertebral severance of the two adjacent ribs, is sufficient to give adequate exposure. In the approach to lesions of the esophagus anywhere except in the lower portion, a resection of the sixth rib throughout most of its length is generally all that is needed. If additional room is required, division of the fifth and seventh ribs, respectively, in their paravertebral portions will give adequate exposure. In those cases in which the lower portion of the esophagus is the site of neoplastic change, resection of the eighth rib on the left side throughout its entire course is usually sufficient to give adequate exposure to the lower esophagus and the diaphragm. This is particularly applicable in those cases in which the diaphragm is incised to facilitate the transphrenic mobilization of the stomach into the thorax.

In some reported cases extensive incisions which extend into the pleural and abdominal cavities have been used.[103, 132, 199, 276]

The approach to the abdominal portion of the esophagus and the lower thoracic portion which is mobilized below may be accomplished in a number of ways. In a patient with a wide costal angle, a midline incision extending from a point just to the left of the ensiform down to the umbilicus usually gives fairly adequate exposure. In a patient with a narrow arch, however, this incision frequently will not suffice. To it may be added a transverse incision or a left costal margin incision, extending from the xiphoid laterally to the anterior axillary line. In many instances, this will not suffice because of the great distance between the costal margin and the diaphragm. In these cases, the mobilization of the costal arch may be done according to the technique of Marwedel, which consists of division of the seventh costal cartilage close to the xiphoid process and the division of the seventh, sixth, and fifth costal cartilages upward, giving wide access to the subphrenic area on the left.

TECHNIQUE

On the basis of our experience, we feel that there are two techniques which may be employed in individual cases in the treatment of carcinoma of the thoracic esophagus. As previously stated, we are convinced that carcinomas involving the thoracic esophagus, except in the lower part, are best extirpated through a thoracicocervical approach. The gastrostomy is done as the first stage and the resection as the second. As a preliminary procedure, a duodenal tube is introduced through the nose into the esophagus as far as it will extend. This facilitates the recognition and mobilization of the esophagus out of its bed. With the patient in the left lateral position, at an angle of 45° so that the posterior surfaces face downward, an incision is made from the parasternal region to just beyond the posterior axillary line over the sixth rib (Fig. 7*a*). The sixth rib is resected subperiosteally throughout the extent of the incision. The pleural cavity is opened through the bed of the sixth rib and the wound edges are separated. If insufficient exposure is obtained, it may be necessary to cut the two adjacent ribs, namely, the fifth and seventh, at the posterior end of the incision. The lung is then retracted medially and anteriorly, exposing the costovertebral gutter. Careful examination of the tumor and of its extent is made in order to determine whether or not the lesion is operable. Unless the tumor is in the region of the aortic arch, it is preferable to mobilize the tumor first, because occasionally after mobilization has been begun, it is apparent that the lesion is inoperable due to extension of the neoplasm to the surrounding viscera, particularly the aorta. If the lesion is in the region of the aortic arch, a preliminary double ligation of the vena azygos major and its division between the ligatures are essential. This should be done by transfixion sutures in order to prevent subsequent hemorrhage. The mediastinal pleura is incised over the esophagus, and by sharp and blunt dissection the esophagus is freed (Fig. 7*b*). In the region of the arch of the aorta are several large esophageal vessels which are branches of the bronchial and intercostal arteries (Fig. 1). It is necessary that these be doubly ligated and divided. If they are torn, troublesome hemorrhage can occur. The other esophageal vessels are quite small and usually can be disregarded in the blunt resection. After a portion of the esophagus has been mobilized, a piece of umbilical

tape is passed around the esophagus, which facilitates further mobilization by exerting some tension on the esophagus. Whenever possible, the vagi should be preserved. If, however, there is apparent involvement of the vagi in the neoplastic mass, they should be divided after injecting them with novocain. The various effects of vagal trauma and severance have been described previously.[70, 104, 160, 173-176, 246, 248, 280] The esophagus is mobilized up under the aortic arch, which usually can be done without difficulty. It is also mobilized down to within a short distance of the diaphragm. After complete mobilization of the thoracic portion of the esophagus, a second team makes an incision in the cervical region, the incision extending from the supraclavicular notch upward for about 8 or 9 cm. along the anterior border of

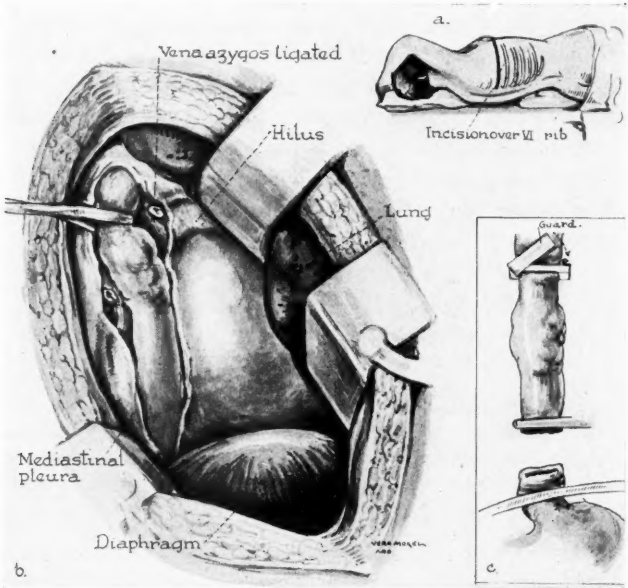

Fig. 7.—Technique of thoracicocervical approach for carcinoma of the thoracic esophagus. *a*, The patient is placed in left lateral position at an angle of 45°, and the incision is made over the sixth rib from the parasternal region to just beyond the posterior axillary line. The rib is resected subperiosteally and the pleural cavity is entered through the bed of the rib. If greater exposure is necessary, the fifth and seventh ribs may be severed paravertebrally. *b*, The vena azygos is severed between transfixation ligatures and the mediastinal pleura is incised. The tumor and esophagus are carefully mobilized. *c*, The esophagus is severed below the tumor between clamps and the lower end is inverted. Special clamps are applied above the tumor, and the esophagus is severed with the cautery between these, following which the guard of the clamp is swung in place, thus effectively covering the severed end of the esophagus.

the left sternocleidomastoid muscle (Fig. 8*c*). The lower end of the wound dissection is carried down to the paraesophageal region by sharp and blunt dissection (Fig. 8*b*). If the left lateral lobe of the thyroid is large, it is necessary for it to be retracted anteriorly, which can be done best by a number of sutures. Care must be taken not to interfere with the inferior thyroid artery. The esophagus, which is easily palpable because of its contained tube, is bluntly mobilized down into the superior thoracic aperture. A long curved forceps is inserted just anterior to the vertebral bodies and directed posteriorly and to the right in the posterior mediastinum. It is necessary for the forceps to be inserted a relatively short distance because of the previous mobilization of the upper part of the esophagus from

below. As soon as the forceps have been introduced into the upper part of the posterior mediastinum, special clamps are applied to the esophagus well above the tumor and well below the tumor. The esophagus is divided by means of a cautery both above and below the tumor between the clamps, and the special guard is swung in place on the upper clamp. This special clamp is similar in construction but smaller in size to those previously described by the authors for use in the Devine colostomy and abdominoperineal resection.[196] Its use here obviates the difficulty of covering carefully the severed end of the esophagus with gutta percha or rubber dam and prevents soiling of the mediastinum during the passage of this end of the esophagus into the cervical wound. A strong ligature is then placed around the esophagus above

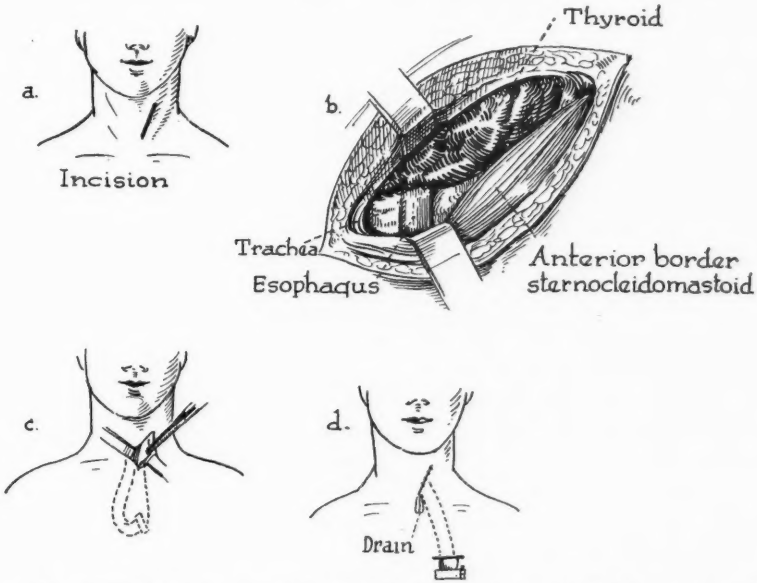

Fig. 8.—Technique of cervical part of thoracicocervical approach for resection of carcinoma of the esophagus. *a*, Incision is made along the anterior border of left sternocleidomastoid muscle, extending from the supraclavicular notch upward for a distance of about 8 or 9 cm. *b*, By blunt and sharp dissection the esophagus is exposed in the depth of the wound, care being taken to preserve the inferior thyroid artery. *c*, After severance of the esophagus through the thoracic wound, a ligature is placed around the upper end near the special clamp and the ends of the ligature are caught with a long forceps previously introduced through the cervical wound. Traction on the forceps delivers the esophagus into the cervical wound. *d*, The delivered segment of the esophagus is tunneled under a skin bridge and brought out through a small transverse incision on the chest.

the clamp and grasped with the forceps which has been introduced from above. The ligature is withdrawn into the cervical region, and then the upper part of the esophagus is brought out of the thorax into the cervical wound (Fig. 8*c*). The proximal end of the distal segment is then ligated and inverted by several layers of interrupted sutures, thus completely covering the stump (Fig. 7*c*). When possible, the mediastinal wound is resutured, and while the thoracic wound is being closed in layers by heavy cotton sutures passed around the ribs to approximate the edges and finer sutures for the pleura and the intercostal muscles, the surgical team working in the cervical region tunnels under the skin of the thorax over a varying distance, depending upon the length of the esophagus, and the mobilized segment is brought under the skin to the outside through a lower transverse incision (Fig. 8*d*). At

least 1 cm. of the esophagus should be allowed to protrude from the skin edges, the wall of the esophagus being sutured to the small transverse incision. The cervical wound is closed completely except for a small drain extending down to the apex of the pleura. A drain is inserted into the thoracic cavity through an intercostal stab wound in the most dependent portion. In those cases in which the tumor is located in the region of the aortic arch and in which it is not possible to get above the tumor, the esophagus with the tumor-bearing portion is brought out through the cervical region, and the neoplastic lesion is removed after the mobilized esophagus has been brought out in the neck. The tunneling under the skin has been used by previous investigators.[2, 183, 240]

Whereas there has been considerable controversy concerning the advisability of drainage in cases of resection of the esophagus, as evidenced by the reports in the literature,[294] we feel that drainage is imperative because of possible contamination. Bengolea[19] was one of the first to use water-sealed drainage.[128] The drainage tube should be introduced into the dependent part of the thorax, should have many fenestra in it, and should extend up into the mediastinum. Positive suction should be applied to the end of the tube, which will aid not only in evacuation of material which will accumulate, but will, as emphasized by Meyer,[174-179] prevent the possibility of a tension pneumothorax.

The advisability of preliminary collapse of the lung is controversial. Hauch, in 1914, was the first to employ preliminary artificial pneumothorax preparatory to resection of the esophagus. Since this time, a number of investigators have advocated its use.[295] In our cases, we have not employed preliminary pneumothorax and feel that it is not a necessary requirement. In order to protect the pleural cavity against infection, Ohsawa suggested vaccination of the pleural cavity by means of a bacterial vaccine. Although we have not had occasion to use it, we believe that rather than use a vaccine as a preparatory measure, it would be far better to employ Steinberg's coli bactragen in those cases in which there is any evidence of contamination. We are of the opinion that equally good results can be obtained as from its preliminary use.

Whereas general anesthesia has been most frequently employed, in a few instances spinal analgesia has been used.[60, 61, 224] Local analgesia is occasionally preferred. We prefer a general anesthetic, preferably with cyclopropane, although ethylene has been satisfactory. The obvious advantage of cyclopropane lies in the higher concentration of oxygen available to the patient, particularly one having a thoracic operation. It should be realized that the problem of anesthesia was one of the factors which delayed the early progress of intrathoracic surgery. The fear of opening the pleural cavity and the consequent pneumothorax led to the development of the differential pressure chamber of Sauerbruch[217] and the positive pressure apparatus of Brauer and Petersen. The subsequent introduction of the method of intratracheal insufflation by Meltzer

and Auer simplified this problem. Whereas it is desirable to have positive pressure available, particularly to bring about a reexpansion of the lung during closure of the chest, we agree with Ohsawa that the use of positive pressure is not absolutely essential. We are equally convinced that intratracheal intubation is not only unnecessary, but also may be actually harmful because of the trauma to the larynx and trachea.

Whereas in lower thoracic esophageal lesions, the transthoracic approach alone has been employed successfully by us as well as others, we are convinced on the basis of clinical and experimental observations that the thoracicoabdominal approach in two stages is preferable. Because of the probability of extension of such malignant lesions into the lymph nodes around the left gastric artery and even the involvement of the nodes in the gastrohepatic omentum, and because of the necessity of

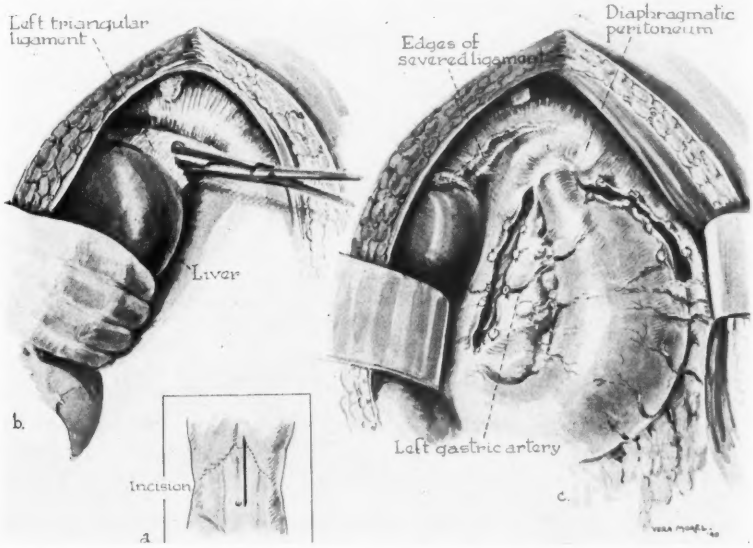

Fig. 9.—Technique of two-stage thoracicoabdominal approach for resection of carcinoma of the lower end of the esophagus. *a*, A high left paramedian incision is made. *b*, Severance of the left triangular ligament permits mobilization of the left lobe of the liver and facilitates exposure of the cardia. *c*, The upper part of the stomach and cardia are mobilized by severance between ligatures of the omentums in this area. In those cases in which there is lymph node involvement along the lesser curvature, the gastrohepatic omentum is severed down to the pylorus.

mobilization of the stomach, we believe that a preliminary laparotomy should always be done; usually through a left paramedian incision or at times through a costal marginal incision, the stomach is freely mobilized (Fig. 9*a*). In order to facilitate exposure, the peritoneal reflection from the undersurface of the diaphragm to the superior surface of the left lobe of the liver, is incised, as suggested by Turner (Fig. 9*b*). This permits mobilization of the left lobe of the liver to the right, giving free access to the region of the cardia. The gastrohepatic omentum is removed entirely from the undersurface of the liver down to the stomach. The left gastric

artery is doubly ligated and divided. Similarly, the left gastroepiploic artery is ligated and divided, as well as the gastrolienal and gastrosplenic ligaments (Fig. 9*c*). In those instances, in which there is no extension of the lesion to the stomach wall, mobilization of the stomach throughout its proximal half is sufficient. On the other hand, if there is extension along the lesser curvature of the stomach, the entire stomach should be mobilized, leaving only the right gastric and the right gastroepiploic arteries intact, as was done in our Case 1. Although it has been contended that the vascularity of the stomach may not be sufficient when only these two arteries remain, it has been shown experimentally by Ohsawa that following such a mobilization of the stomach, frequently there is disturbance in the circulation in the region of the greater curvature in the fundi. This, however, is only temporary, and after a week's time the nutrition is sufficient. This is another reason why a preliminary mobilization of the stomach is desirable before resection of the diseased portion of the esophagus and anastomosis are attempted. In those cases in which

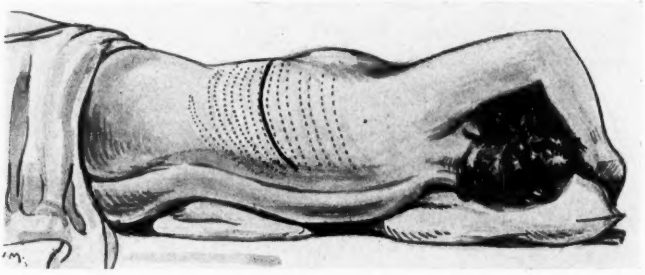

Fig. 10.—Technique of two-stage thoracicoabdominal approach for resection of carcinoma of the lower end of the esophagus. About one week after the procedure shown in Fig. 9 has been performed, the thoracic stage is carried out. With the patient in the right lateral position, an incision is made over the left eighth rib from its angle posteriorly to its costochondral junction and the rib is resected subperiosteally. The pleural cavity is entered through the bed of the rib.

there is little or no involvement of the stomach, a gastrostomy performed in the pyloric end of the stomach should be done at this operation. If, however, there is extensive involvement of the lesser curvature, necessitating extensive mobilization, it is preferable to perform a jejunostomy at the preliminary procedure, as the greater portion of the lesser curvature of the stomach will be removed as was done in one of our cases (Case 1). The abdomen is closed in layers, without drainage aside from the gastrostomy or the jejunostomy. Approximately a week later, with the patient in the right lateral position, under gas-oxygen anesthesia, a long incision is made over the course of the eighth rib (Fig. 10). This rib is resected subperiosteally throughout its whole length. The pleural cavity is opened through the bed of the rib and the lung is retracted medially and anteriorly. The extent of the carcinoma is determined in order to ascertain its operability. The phrenic nerve is crushed after injection with novocain. An incision is made in the mediastinal pleura overlying the esophagus, and the esophagus is mobilized from its surrounding structures. An incision is made in the diaphragm from the esophageal hiatus outward for a varying distance depending upon the degree of exposure required. After incising the reflection of the peritoneum from the undersurface of the diaphragm on to the stomach, the previously mobilized stomach can be brought up into the thoracic cavity without difficulty (Fig. 11). By means of an umbilical tape passed around the lower end of the esophagus, the esophagus is freed up for a distance well above the tumor (Fig. 11). Crushing clamps are applied to the stomach below the lesion, and the

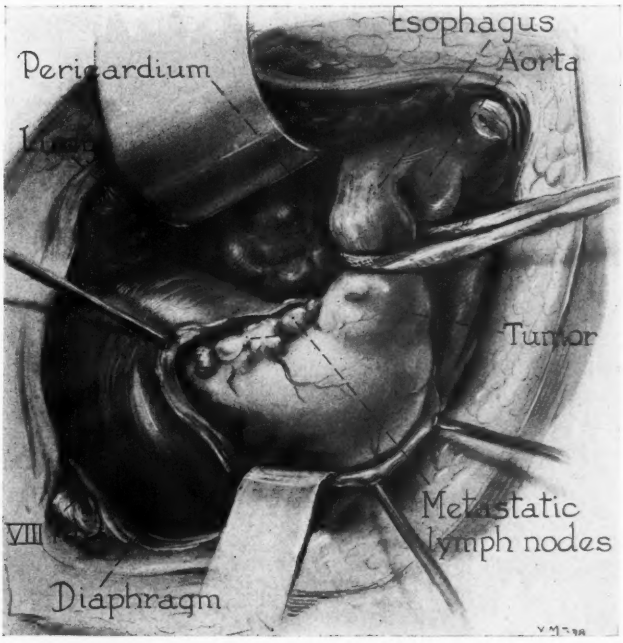

Fig. 11.—The phrenic nerve having been crushed, the diaphragm is incised radially from the hiatus outward for a varying distance depending upon the degree of exposure required and the peritoneal cavity entered. The previously mobilized stomach may then be brought up easily into the pleural cavity.

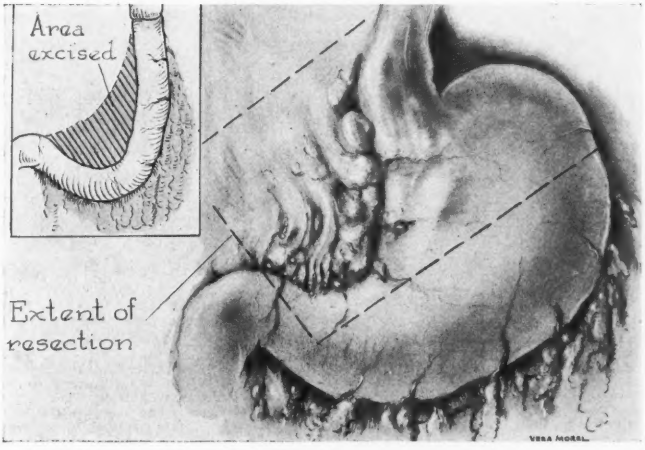

Fig. 12.—Drawing made from operation (Case 1) showing extent of resection. A gastric tube was made from the greater curvature half of the stomach.

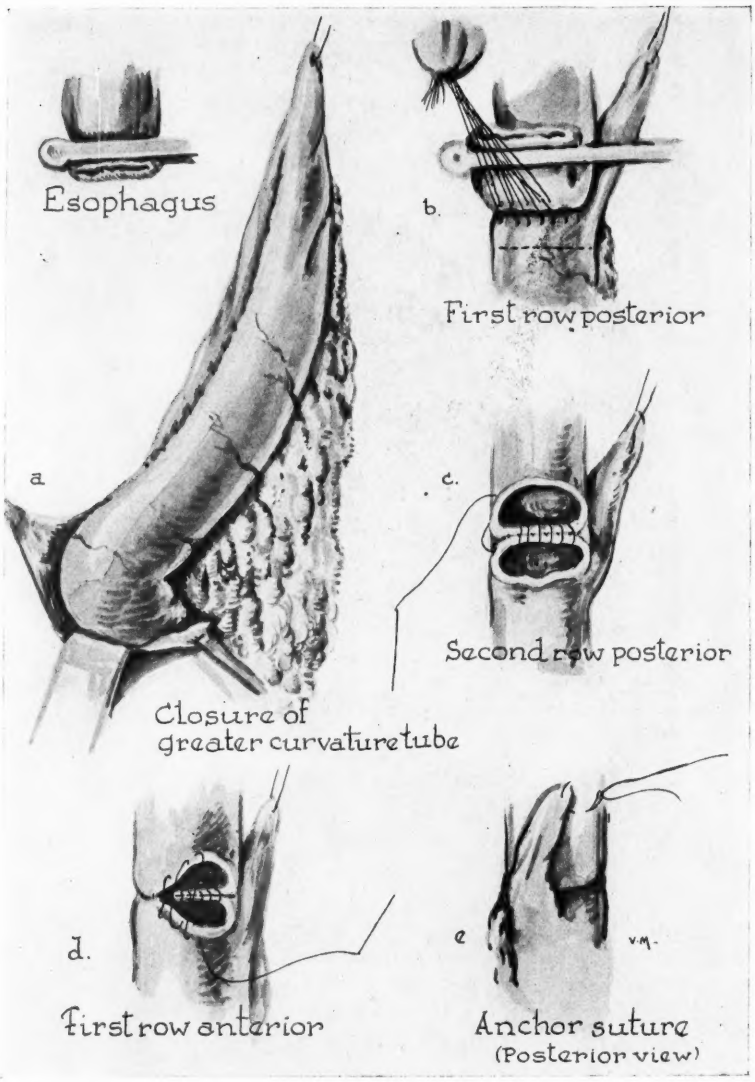

Fig. 13.—Technique of esophagogastrostomy during second stage of thoracico-abdominal approach for resection of carcinoma of the lower end of the esophagus. *a*, After resecting the tumor and lesser curvature half of stomach, a long gastric tube is made by suturing the edges of the greater curvature half of stomach. *b*, The esophageal end is anastomosed to the anterior wall of the stomach by placing the first posterior row of interrupted sutures a short distance from the line of incision in the stomach, as indicated by the dotted line. *c*, The edge of the esophageal opening is then attached to the edge of the gastric opening by a through-and-through continuous suture which is brought anteriorly as a Connell suture, thus closing the anastomosis as shown in *d*. This is followed by an anterior row of interrupted seromuscular sutures, and finally (*e*) the stomach is further anchored to the esophagus by attaching the upper pouch of the gastric tube to the posterior wall of the esophagus. A small piece of omentum may be wrapped around the anastomotic suture line.

stomach is divided with the cautery between the two clamps. The upper end of the stomach is then closed by inverting the edges. In those cases in which the tumor extends down along the lesser curvature, it is possible to remove the entire lesser curvature, leaving only the greater curvature (Fig. 12). By suturing the edges of the remaining greater curvature, a long gastric tube is produced (Fig. 13*a*). This is brought up further into the thoracic cavity, and with a clamp still attached to the distal end of the esophagus below the tumor and by means of interrupted sutures, the posterior aspect of the esophagus wall above the tumor is anastomosed to the anterior surface of the gastric tube (Fig. 13*b*). After the introduction of the posterior row of interrupted cotton sutures, a rubber-covered clamp is applied to the stomach and a transverse incision is made about 1 cm. beyond the posterior row of sutures (Fig. 13*b*). A clamp is applied to the esophagus 1 cm. from its attachment to the gastric wall, and the esophagus is divided above the clamp. Constant suction is maintained through the tube introduced from above, which removes all secretion which might be present in the segment. Posteriorly, by means of a continuous double 0 chromic suture, passing through all layers, the edges are approximated (Fig. 13*c*). This is continued anteriorly as a Connell suture (Fig. 13*d*). Interrupted cotton sutures are used anteriorly for inversion. The gastric wall is further brought up on the wall of the esophagus by a second layer of cotton sutures anteriorly. As a final procedure, the stomach is sutured to the undersurface of the diaphragm lateral to the anastomosis, and in this way any tension on the suture line is prevented. An important part of the operation is the wrapping of a piece of omentum around the completed anastomosis. The advantage of this has been demonstrated experimentally by Araki. The wound is closed in layers following the introduction of the drainage tube in the dependent portion of the wound, to which constant suction is applied.

CASE REPORTS

CASE 1.—Mrs. B. J., a white female, 49 years of age, was admitted to Charity Hospital on May 11, 1938, complaining chiefly of difficulty in swallowing which had begun approximately five months previously and which had become progressively worse until admission, at which time she could swallow only soft foods and fluids. She had had no pain, but had lost about 10 pounds in weight. Past history, family history, and social history were not significant.

Physical examination revealed a fairly well-developed white female appearing 45 years of age, who seemed to be in good general condition. Temperature was normal; pulse, 80; blood pressure, 135/90. Detailed physical examination revealed no gross abnormalities. Laboratory findings: Wassermann showed a negative reaction; urinalysis revealed no abnormalities. Blood count showed red blood cells, 4,950,000; hemoglobin, 90 per cent; white blood cells, 9,000, with polymorphonuclear cells, 52 per cent. Roentgenographic studies were made on May 14, 1938. Fluoroscopic examination of the esophagus showed a stricture in the lower end, with an irregular defect most likely due to carcinoma (Fig. 14). Esophagoscopy on May 18 revealed stricture of the esophagus and an ulceration just above the cardia. A biopsy was made but showed no evidence of malignancy. Esophagoscopy was repeated on June 1, but findings were similar to those of the previous examination. The patient seemed to be able to swallow better after these examinations and left the hospital on June 2, 1938.

She returned on June 20, stating that her dysphagia had become worse. Fluoroscopic examination on June 24 revealed a filling defect at the lower end of the esophagus, which was more prominent than at the previous examination (Fig. 15). Esophagoscopy on June 22 revealed the lesion as previously observed, and another

biopsy was made. However, the tissue removed showed no evidence of malignancy and the patient was discharged on June 25, 1938.

The patient was readmitted on July 25, complaining of marked dysphagia and inability to swallow anything but fluids. Fluoroscopic examination on July 29 again revealed the filling defect and obstructing lesion at the lower end of the esophagus and cardia which had obviously progressed since the previous study (Fig. 16). Esophagoscopy was performed on July 28, and a stricture and an ulcerating mass were found at the lower end of the esophagus just above the cardia, biopsy of which again revealed no evidence of malignancy. However, it was felt that the condition was malignant and the patient was transferred to surgery. On July 4, 1938, under

Fig. 14.

Fig. 15.

Fig. 14.—Case 1. Anteroposterior roentgenogram of esophagus following ingestion of barium meal. This was made on May 14, 1938, and reveals a stricture at the lower end of the esophagus, with an irregular defect which the roentgenologist believed was most likely due to a malignant lesion.

Fig. 15.—Case 1. Roentgenogram of esophagus following ingestion of barium meal, June 24, 1938, approximately six weeks later. Obstruction and filling defect at the lower end of the esophagus are definitely more prominent.

ether anesthesia, the peritoneal cavity was entered through a right paramedian incision. Exploration revealed a firm, nodular mass at the cardiac end of the stomach, extending up above the diaphragm. A few nodes were found in the lesser omentum and a small nodule in the liver, biopsy of which subsequently revealed only chronic inflammatory tissue. A gastrostomy was then done at the lower end of the stomach. On Sept. 22, 1938, under nitrous oxide-ether anesthesia, with the patient in the right lateral position, an incision was made over the left eighth rib from the posterior axillary line to its costochondral junction, and the rib was resected through the entire extent of the incision (Fig. 10). The pleural cavity was entered through the bed of the rib. Exploration revealed a firm, nodular tumor involving the cardiac end of the esophagus and extending above the hiatus for about 4 cm. The left

phrenic nerve was injected with novocain and crushed. The pleura around the tumor was incised, and by sharp and blunt dissection the esophagus was freed from its bed from a few centimeters above the tumor down to the hiatus. The diaphragm was then incised from the hiatus radially outward for a distance of about 8 cm. and the peritoneal cavity was entered. The stomach was mobilized and brought up through the opening in the diaphragm into the pleural cavity (Fig. 11). Because of the lymph node involvement along the lesser curvature, the gastrohepatic ligament was divided between ligatures and the stomach was freed of this attachment down to the pylorus. The stomach was then divided with the cautery between clamps applied in such a fashion that the entire lesser curvature half of the stomach, including the cardia and upper part of the fundus, was resected (Fig. 12). The

Fig. 16.

Fig. 17.

Fig. 16.—Case 1. Roentgenogram of esophagus following ingestion of barium meal, July 29, 1938, almost five weeks later. The progress in the obstructing lesion is obvious.

Fig. 17.—Case 1. Roentgenogram of esophagus following ingestion of barium meal, Oct. 26, 1938, approximately one month after resection and esophagogastrostomy. There is no evidence of obstruction to the path of barium.

esophagus was also divided between clamps applied well above the tumor and the segment removed. The opening in the stomach was closed with two layers of sutures, thus forming a gastric tube with an intact greater curvature. This was brought up behind the esophagus and an end-to-side esophagogastrostomy was performed (Fig. 13), with several layers of sutures. The opening in the diaphragm was then closed and attached to the gastric tube so that there was no apparent tension on the anastomosis suture line. A thoracotomy tube with several openings was placed in the pleural cavity and brought out through a stab incision in the posterior axillary line at the tenth intercostal space. The wound was closed in layers.

The specimen revealed a large ulcer irregularly round, which had completely encircled the cardia, with a dirty, friable base and raised firm edges, which on microscopic examination was found to be adenocarcinoma.

Following the operation the patient's condition was good. She was given a transfusion of 500 c.c. of unmodified blood. Her subsequent progress was uneventful. The thoracotomy tube to which constant suction had been applied was removed approximately one week after the operation. On Oct 7, 1938, she was able to take food by mouth. On Oct. 15 she was up and about in the ward. The gastrostomy tube had been removed and the opening had almost completely closed. On Oct. 26 fluoroscopic examination of the esophagus and stomach following barium meal revealed no evidence of obstruction to the path of the barium (Fig. 17). She was discharged on Nov. 5, 1938, in excellent condition.

The patient was observed again in November, 1939, a little over a year after the operation, and was apparently in good condition.

Comment.—This case further emphasizes the ubiquitous cry for early diagnosis. Obviously, had this patient been operated upon when she was first observed, such an extensive operation would have been obviated. Moreover, the risk of operation and the possibility of recurrence would have been decreased. The case also illustrates the difficulty of early diagnosis and raises the question of exploratory operation in such instances.

CASE 2.—O. W., a negro female, 40 years of age, was admitted to Charity Hospital on Sept. 7, 1938, complaining chiefly of nausea and vomiting, particularly following the ingestion of food. This had begun about four months previously and had become progressively worse. The vomitus usually consisted of recently ingested food. The patient complained of no pain. During this period of time she lost about 30 pounds in weight. Past history, family history, and social history were not significant. Physical examination revealed a negro female, about 45 years of age, of sthenic habitus and obviously undernourished. Except for the appearance of slight emaciation and dehydration, no other gross abnormalities were observed. Temperature was 99° F.; pulse, 86; blood pressure, 110/80. Laboratory findings included a negative Wassermann; urinalysis reveals no abnormalities. Blood examination showed red blood count, 3,100,000; white blood count, 7,200. On Sept. 12, 1938, fluoroscopic examination revealed a small ulcer crater and obstruction beginning just above the esophageal opening at the cardia (Fig. 18). On Sept. 15 fluoroscopic examination showed a small mass of barium the size of a pea retained in the crater at the end of one week following previous examination. Following the ingestion of barium, there was a definite filling defect of the esophagus at this opening into the cardia of the stomach. The appearance was suggestive of carcinoma of the terminal end of the esophagus and adjacent portion of the cardia. An esophagoscopy was scheduled to be done, but the patient deserted on Sept. 29, 1938.

She returned to the hospital on Oct. 19, 1938, complaining of increased difficulty in swallowing, and at this time she was able to take only fluids. Esophagoscopy was done on Nov. 16, 1938, which revealed a granulating mass at the lower end of the esophagus which bled easily upon manipulation. Biopsy was done which subsequently revealed adenocarcinoma.

On Oct. 29 operation was performed. The peritoneal cavity was entered through a left paramedial incision, under local analgesia. Exploration revealed a mass at the cardiac end of the stomach extending up into the esophagus above the diaphragm. A few lymph nodes were found which involved the lesser omentum. A gastrostomy (Stamm) was performed and the wound was closed. On Nov. 22 operation was

performed in a similar manner as described in Case 1. Under nitrous oxide-ether anesthesia, the left pleural cavity was entered through the bed of the subperiosteally resected eighth rib. The phrenic nerve was injected with novocain and crushed. The lower end of the esophagus including the tumor was freed. A radial incision was made in the diaphragm, extending laterally from the hiatus, and the stomach was carefully mobilized and brought up into the pleural cavity. The tumor mass including the lesser curvature half of the stomach and the lower end of the esophagus was resected, and an esophagogastrostomy was performed as an end-to-side anastomosis.

The specimen revealed a large irregular ulcer, with a friable, reddish-gray, granulating base and firm, raised edges. Microscopic examination demonstrated adenocarcinoma.

Fig. 18.—Case 2. Roentgenogram of esophagus following ingestion of barium meal, showing obstructive filling defect at the lower end of the esophagus and cardia.

Following the operation, the patient's condition seemed to be fairly satisfactory. She was given a transfusion of unmodified blood. The next day her temperature rose to 103° F., but gradually dropped to 100° F. during the next two days. Her condition during this time seemed to be fairly good. On the fourth postoperative day, the temperature rose again and a large quantity of foul, seropurulent fluid appeared in the thoracotomy tube. The patient was given neoarsphenamine and blood transfusions, and irrigations were done through the thoracotomy tube with sterile normal saline. The following day her general condition seemed to be weaker and there was evidence of pneumonia in both lower lobes. Respiration became labored. The patient died on the morning of Nov. 27, 1938. A post mortem was not permitted, but the patient's death was believed to be due to empyema and pneumonia.

Comment.—Whereas this patient's death was obviously due to pneumonia and infection, the possibility of a successful result probably would have been increased had she been operated upon at her first admission. Her general condition was definitely worse at her subsequent admission, and consequently her resistance was diminished, which again emphasized the necessity of early diagnosis and intervention.

In the collected cases infection was one of the most prominent causes of death. The authors believe that in the future the use of coli bactragen as suggested above may be effective in controlling such infections.

CASE 3.—T. H., a negro male, 31 years of age, was admitted to Charity Hospital on Feb. 7, 1939, with the chief complaint of difficulty in swallowing which was first observed on Dec. 15, 1938. This gradually became worse until Jan. 21, 1939, when a small piece of meat "lodged in his throat." On Jan. 23 it was removed by esophagoscopy, which revealed a mass projecting into the lumen of the esophagus. A biopsy was done and a diagnosis of carcinoma was made. He was then referred to Charity hospital. The difficulty in swallowing was not associated with any pain. This dysphagia had progressed to such an extent that even the swallowing of water was difficult. He had not expectorated nor vomited blood. He had lost about 10 pounds in weight during the past two months. Past history, social history, and family history were not significant.

Fig. 19.—Case 3. Roentgenogram of esophagus following ingestion of barium meal, showing stenotic filling defect extending from the upper border of the seventh dorsal vertebra to the upper half of the ninth.

Physical examination revealed a colored male, 5'6" in height, weighing about 120 pounds, appearing about 30 years of age, of sthenic habitus, and apparently not acutely ill. No gross abnormalities were observed, except that he appeared somewhat undernourished and there were a few carious teeth. Temperature was normal; pulse, 90; respiration, 17; blood pressure, 110/76. Laboratory findings showed a negative Wassermann, and urinalysis revealed no abnormalities. The red blood count was 3,500,000; hemoglobin, 80 per cent; white blood count, 5,500, with 65 per cent polymorphonuclear cells. Roentgenograms were made Feb. 8, 1939. Views of the esophagus following the ingestion of barium showed a large filling defect extending from the upper border of the seventh dorsal vertebra to the upper half of the

ninth body (Fig. 19). There was marked dilatation of the esophagus above this region. A small amount of the opaque material emptied through what was apparently a fistulous tract in the tumor mass and reached the stomach. The chest and pelvic bones showed no evidence of metastasis. On Feb. 10 esophagoscopy revealed an ulcerating, friable mass projecting into the lumen of the esophagus, which bled easily on manipulation and had the gross characteristics of a fungating malignant lesion. The lumen was almost completely occluded. A biopsy was made which subsequently revealed the lesion to be adenocarcinoma.

Operation was performed Feb. 24, 1939, under cyclopropane anesthesia. The peritoneal cavity was entered through a left paramedian incision. Exploration revealed no evidence of metastasis to the lesser curvature and to the liver. A Kader-Senn gastrostomy was performed in the anterior wall of the stomach. The patient's progress following this procedure was very satisfactory and he seemed to improve in strength.

On March 28, 1939, esophagectomy was carried out. Under nitrous oxide-ether anesthesia, with the patient in the left lateral position, an incision was made over the right sixth rib, extending from the costochondral junction anteriorly to the transverse process posteriorly (Fig. 7). The rib was subperiosteally resected throughout the extent of the incision and the pleural cavity was entered through the bed of the rib. Exploration revealed the tumor mass immediately below the vena azygos about 4 cm. in extent, with several adjacent firm nodules. The mediastinal pleural was incised, and by blunt and sharp dissection the tumor was carefully freed from its bed as well as the esophagus well above and below the tumor. Several large vessels entering the esophagus were divided between ligatures. The right vagus was involved by the tumor and was severed above. Crushing clamps were applied to the esophagus below the tumor and the esophagus was divided with the cautery. The lower end was closed by several layers of inverting sutures. The lower end of the upper segment was carefully covered by a piece of rubber dam after having been doubly ligated. The esophagus including the tumor was then mobilized under the arch of the aorta and freed as high as the suprasternal notch. The chest wound was closed after placing a drain in the pleural cavity out through the ninth intercostal space. An incision was then made along the border of the left sternocleidomastoid muscle, extending from the sternoclavicular junction for about 7 cm. upward. By sharp and blunt dissection the esophagus was exposed and brought out through the wound which was closed around it except for a small drain at the lower end. The esophagus was then divided above the tumor between crushing clamps, leaving a few centimeters of the normal esophagus projecting from the neck wound. This was carefully ligated and the end was cauterized.

Specimen.—The specimen measured approximately 12 cm. in length and contained a firm nodular mass about 7 cm. in length involving the entire circumference of the esophagus. A few firm lymph nodes were attached to the wall. On opening the esophagus by longitudinal section, the ulcer was observed with a dirty, friable, granulating base and firm raised edges (Fig. 20). Microscopic examination revealed adenocarcinoma.

The patient's condition at the end of the operation was satisfactory. He was given a transfusion of 500 c.c. of unmodified blood, and normal glucose and saline intravenously. During the first few days postoperatively his temperature did not rise over 101° F., and he seemed to be progressing very satisfactorily. However, on the fifth postoperative day, his temperature rose to 102° F., and he continued to have a septic type of fever during the following week. The drainage tube in the chest revealed foul, sanguinopurulent secretions, indicating the presence of infection. The patient was given neosalvarsan and his temperature began to drop and

his general condition seemed somewhat better. There was evidence of infection in the wound of the chest as well as in the neck. The pleural cavity was irrigated with azochloramide. Following this short period of improvement, the patient again began to run a septic fever, with temperatures ranging between 101 and 103° F., and his condition was becoming progressively worse. On the evening of May 6, 1939, the patient had a marked hemorrhage from the wound of the chest and went into shock from which he recovered following appropriate therapy and blood transfusion. On the morning of May 7, 1939, he had another profuse hemorrhage and again went into shock and died within a few minutes.

Fig. 20.—Case 3. Resected specimen of esophagus, showing large ulcer with friable, granulating base and irregular, firm, raised edges. Microscopic examination revealed adenocarcinoma. The lymph nodes observed on either side were found to be involved.

Post Mortem.—On opening the pleural cavity, the right lung was found to be collapsed and consolidated, and the right side of the thorax contained about 1,000 c.c. of clotted blood. A large infected sinus tract was found to surround the lower stump of the esophagus and to communicate with the right pleural cavity, extending into the mediastinum. The closed stump of the lower segment of the esophagus was intact. Firm, rubbery, pale, gray tissue was present in the posterior mediastinum in the region formerly occupied by the midportion of the esophagus. The hilum of the right lung had been infiltrated by the mass which, on microscopic examination, proved to be malignant and similar in character to the lesion in the esophagus.

Diagnosis.—Hemorrhage into the right pleural cavity, atelectasis and gangrene of the right lung, mediastinitis, metastatic adenocarcinoma of the right lung and mediastinal tissues.

Comment.—Although it was realized at the time of operation that the lesion was extensive and bordered on inoperability, it was felt that because the tumor could be mobilized, resection was justified. Whereas a "cure" would be questionable, the patient's survival period may have been extended.

The infection in this case undoubtedly occurred at the time of operation, and although no gross spillage occurred, contamination is difficult to avoid. It is believed, however, that the use of the special clamps with the guard as suggested above would decrease considerably the possibility of such infections.

CASE 4.—W. R., a negro male, 54 years of age, was admitted on Dec. 30, 1939, complaining chiefly of inability to swallow, which had begun approximately three months previously. This was not associated with pain, but the patient had the distinct sensation of food "sticking in his throat." The dysphagia had become progressively worse until at the time of admission he was unable to swallow anything but fluids. He had lost about 30 pounds in weight. Past history, family history, and social history were not significant.

Physical examination revealed a negro male, approximately 55 years of age, fairly well developed, but slightly emaciated. Detailed examination revealed a few carious teeth but no other gross abnormalities. Temperature was 99° F.; pulse, 74; blood pressure, 130/70.

Fig. 21.—Case 4. Roentgenogram of esophagus following ingestion of barium meal, showing almost complete obstruction in the midportion of the esophagus.

The Wassermann reaction was positive; urinalysis showed no abnormalities. Blood chemistry was normal, with a red blood count of 4,100,000; hemoglobin, 70 per cent; white blood count, 8,600; with polymorphonuclear cells, 63 per cent. Fluoroscopic examination on Jan. 6, 1940, revealed an obstruction about the middle half of the esophagus, with dilatation above (Fig. 21). Esophagoscopy on Jan. 8 revealed a fungating granular mass which almost completely occluded the lumen of the esophagus approximately 28 cm. from the incisor teeth. The mass bled easily upon manipulation. Biopsy was made which subsequently revealed squamous cell carcinoma.

Operation was done on Jan. 12, 1940, under cyclopropane anesthesia. The peritoneal cavity was entered through a right paramedian incision and gastrostomy

(Spivak) was done. No evidence of metastasis was found on exploration. In the operation on March 1, 1940, under nitrous oxide-ether anesthesia, an incision was made over the right sixth interspace and the sixth and seventh ribs were sectioned paravertebrally. The right pleural cavity was entered. Esophageal tumor was found just below the azygos vein about 6 cm. in extent. The operative details are, in general, similar to those of Case 3. The esophagus was severed between clamps, with a cautery below the tumor and the lower end inverted. The upper end of the esophagus including the tumor was mobilized as high as the neck, and the thoracotomy wound was closed after placing the thoracotomy tube through the ninth interspace in the posterior axillary line. An incision was then made along the anterior border of the left sternocleidomastoid muscle and the esophagus was delivered through the wound to the outside.

Specimen.—The specimen consisted of a segment of the esophagus containing a firm tumor mass in its midportion, about 6 cm. in length. On section an ulcer was observed with a dirty, grayish, bleeding, granular base and firm, raised edges. Microscopic examination revealed squamous cell carcinoma.

The patient's condition immediately following the operation seemed to be satisfactory, but he was given a transfusion of unmodified blood. The following morning the patient's condition seemed to be fairly satisfactory. Temperature was 101° F., and the neck wound was dressed and seemed to be in good condition. That afternoon the patient became very restless and respiration became quite labored; he died within a few hours.

Post Mortem.—Examination revealed collapse of the right lung and a small amount of serosanguineous fluid in the right pleural cavity. At the cardioesophageal junction there was found a firm, small nodule, approximately 3 cm., which subsequently proved to be a metastatic carcinoma. The upper lobe of the left lung showed evidence of consolidation and pneumonia.

SUMMARY

The relatively high and apparently increasing incidence of carcinoma of the esophagus, approximately 5 per cent of all carcinomas, its preponderance of occurrence in the thoracic portion, and its obstinacy to all other forms of therapy clearly emphasize its surgical significance.

The various difficulties which have attended the surgical approach to this vexing problem are briefly reviewed.

A comprehensive review of the literature reveals that multivarious types of operations have been proposed and performed for the resection of esophageal carcinoma. However, in general, they can be classified into five groups: (1) thoracicocervical; (2) thoracicoabdominal; (3) thoracic; (4) abdominal; and (5) abdominocervical. These are reviewed and critically analyzed.

Of the total number of 195 collected cases, including the authors', of carcinoma of the esophagus in which resection was performed, 140 patients died, giving an operative mortality of 71.8 per cent.

The two types of operative procedures which are generally indicated for carcinoma of the esophagus, in the authors' opinion, are the one-stage thoracicocervical and the two-stage thoracicoabdominal. The techniques of both and the authors' modifications are described in detail and are illustrated.

Four cases operated upon by the authors are presented. The lesion was in the midportion of the esophagus in two cases and in the lower end in the others. One patient is still living over a year and a half since operation.

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(*See discussion on page* 470.)

EXPERIMENTAL ESOPHAGOGASTROSTOMY

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IN NOVEMBER, 1938, one of us (B. N. C.) resected by way of a transpleural approach a portion of the cardiac end of the stomach and the lower 3 cm. of the esophagus for a carcinoma situated in the cardia. After the resection an esophagogastrostomy, of the type in which the end of the esophagus was introduced *into* the stomach through an incision in the fundus, was performed. The patient made an uneventful recovery from the operation and the wound in the chest healed by first intention. However, a stricture developed at the site of the anastomosis which was in part, at least, responsible for her death nine months later. In May, 1939, a second patient was operated upon (J. S. and B. N. C.) in a similar manner. Here, too, a stricture developed after an uneventful convalescence and still requires an occasional dilatation in order for the stoma to function. The occurrence of a stricture in each of these two cases operated upon by a well-recognized method advocated by several surgeons has caused us to perform a set of experiments on fifty-two dogs. The results of these experiments are set forth in this paper. (See Table I.)

HISTORICAL REVIEW

The earliest experimental studies on esophagogastrostomy were carried out by Biondi[1] in 1895. From the brief report of these experiments, it appears that a transpleural approach was used. The stomach was drawn up into the chest and an intrathoracic esophagogastrostomy was done by anastomosing the end of the esophagus with the fundus of the stomach. No figures are available as to the number of dogs operated upon or the results.

In 1901 Dobromysslow[2] successfully resected 4 cm. of the lower esophagus in one dog and reunited the ends by two rows of silk sutures. This was in reality an end-to-end suture of the esophagus rather than an esophagogastrostomy. At the end of three weeks, satisfactory healing with slight dilatation of the esophagus proximal to the line of anastomosis was found at autopsy.

The experimental work of A. Gosset[3] was reported in 1903. Using a transpleural approach and bringing a cone of the stomach up through a small opening in the diaphragm, he performed a side-to-side anastomosis between the two organs. A continuous suture uniting the whole thickness of the esophagus and stomach was placed and reinforced by a second

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continuous row involving only the outer coats. This technique was carried out upon a human cadaver and the operation was performed upon one dog. Gosset emphasized the importance of anchoring the intrathoracic portion of the stomach by means of suturing the same to the pleura. This is apparently the first record of an attempt to relieve tension by anchoring the stomach.

Sauerbruch[4] made a lengthy report of both experimental and clinical work upon the esophagus in 1905. The resection of more than 7 cm. of the esophagus and anastomosis by end-to-end suture were found to be followed by leakage in every instance. This leakage was ascribed to tension on the line of suture. He performed a successful anastomosis in three out of twenty attempts in which an intrathoracic esophagogastrostomy was done. Failure occurred in each of six efforts to anastomose the end of the esophagus to the fundus of the stomach in the manner of a Witzel gastrostomy. A two-stage procedure in which the lower esophagus and cardia were invaginated into the stomach and the inverted portions resected later through the stomach also failed because of leakage at the suture line. Finally, Sauerbruch resorted to the use of a Murphy button and recommended this as the most effective procedure.

In 1909 Willy Meyer[5] reported ten esophagogastrostomies in dogs. In six animals, by means of a transpleural approach, the lower one-third of the esophagus was resected and the proximal stump of the esophagus anastomosed to the fundus of the stomach. Following resection the distal end of the proximal stump of the esophagus was closed with a ligature of rapidly absorbable catgut. The distal esophageal stump was closed and left in the thorax. By means of a small opening made through the diaphragm lateral to the esophageal hiatus, a portion of the fundus of the stomach was pulled up into the thorax and joined to the posterior wall of the proximal stump of the esophagus with a row of interrupted silk sutures. After excising an elliptical area of serosa and muscularis from the fundus and then slitting through the mucosa, the end of the esophagus was introduced into the lumen of the stomach. The catgut ligature closing the end of the esophagus was left in place. Three of the six dogs died, one of hemorrhage in twelve hours, one of tension pneumothorax in forty-eight hours and one of empyema six days after operation. The anastomosis was stated to be functioning well in this last animal. Only one of the three dogs surviving the operation lived longer than ten days, the others dying of slow necrosis of the stomach and of distemper. Well-functioning anastomoses were found in these three animals. A slight modification of the above-described method was used upon four other dogs. Shock, hemorrhage, and diaphragmatic hernia proved fatal for three of these animals. The other died on the fourth postoperative day, and at autopsy the implanted lower end of the esophagus was found inverted back into the

TABLE I

DETAILED STUDY OF EXPERIMENTS

DOG NO.	METHOD	ANCHORAGE	DURATION OF LIFE (DAYS)	COMPLICATION				CAUSE OF DEATH
				STRICTURE	PERFORATION	DIPHRAGMATIC HERNIA	ACUTE DILATATION OF STOMACH	
2	End-to-side anastomosis to circular defect in stomach	None	3	0	Yes	0	0	Empyema
94	End-to-side anastomosis to circular defect in stomach	None	4	0	Yes	0	0	Empyema and pneumothorax
97	End-to-side anastomosis to circular defect in stomach	None	110 (living)	0	0	0	0	Living
19	End-to-side anastomosis to circular defect in stomach	Stomach only	85	0	0	0	0	Inanition (constriction of stomach by diaphragm)
25	End-to-side anastomosis to circular defect in stomach	Stomach only	7	0	Yes	0	0	Empyema and pneumothorax
29	End-to-side anastomosis to circular defect in stomach	Stomach only	26	0	0.	0	0	Pneumonia (constriction of stomach by diaphragm)
32	End-to-side anastomosis to circular defect in stomach	Stomach only	3	0	Yes	0	0	Empyema
33	End-to-side anastomosis to circular defect in stomach	Stomach only	14	0	0	0	0	Atelectasis; vegetative endocarditis
35	End-to-side anastomosis to circular defect in stomach	Stomach only	190 (living)	0	0	0	0	Living
38	End-to-side anastomosis to circular defect in stomach	Stomach only	3	0	Yes	0	0	Empyema and pneumothorax
55	End-to-side anastomosis to circular defect in stomach	Stomach only	5	0	0	0	0	Distemper
9	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	10	0	0	0	0	Distemper

42	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	17	0	0	0	0	Distemper
43	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	149	0	0	0	0	Pneumonia (distemper)
44	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	16	0	0	0	0	Wound infection; acute liver necrosis; sulfapyridine given
49	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	9	0	0	0	0	Distemper
50	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	29	0	0	0	0	Distemper
56	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	11	0	0	0	0	Distemper
57	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	50	0	0	0	0	Distemper
135	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	92	0	0	Yes	0	Diaphragmatic hernia; healing ulcer
136	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	23	0	0	0	0	Lung abscess, acute necrosis liver; sulfapyridine given
139	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	82 (living)	0	0	0	0	Living
148	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	76 (living)	0	0	0	Yes	Living
153	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	74	0	0	0	Yes	Gastric ulcer; acute dilatation of stomach
830	End-to-side anastomosis to circular defect in stomach	Stomach and esophagus	75	0	0	Yes	Yes	Acute gastric ulcer; diaphragatic hernia
80	End-to-side anastomosis to linear slit in stomach	None	3	0	Yes	0	0	Empyema and pneumothorax
86	End-to-side anastomosis to linear slit in stomach	None	4	0	Yes	0	0	Empyema and pneumothorax
87	End-to-side anastomosis to linear slit in stomach	None	4	0	Yes	0	0	Empyema and pneumothorax

TABLE I—CONT'D

DOG NO.	METHOD	ANCHORAGE	DURATION OF LIFE (DAYS)	COMPLICATION				CAUSE OF DEATH
				STRICTURE	PERFORATION	DIPHRAGMATIC HERNIA	ACUTE DILATATION OF STOMACH	
62	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	45	0	0	0	0	Pneumonia and lung abscess
63	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	49	0	0	0	0	Pneumonia
67	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	8	0	0	0	0	Distemper
68	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	20	0	0	0	0	Distemper
69	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	85	0	0	0	0	Distemper
125	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	110 (living)	0	0.	0	0	Living
126	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	110 (living)	0	0	0	Yes	Living
129	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	107	0	0	0	0	Distemper
131	End-to-side anastomosis to linear slit in stomach	Stomach and esophagus	8	0	0	0	0	Infarct of spleen; ruptured spleen
70	Esophagus implanted into stomach	None	2	0	Yes	0	0	Empyema and pneumothorax
72	Esophagus implanted into stomach	None	2	0	Yes	0	0	Empyema and pneumothorax

75	Esophagus implanted into stomach	None	3	0	Yes	0	0	Empyema and pneumothorax
89	Esophagus implanted into stomach	Stomach only	2	Yes	0	0	Yes	Acute dilatation of stomach
108	Esophagus implanted into stomach	Stomach only	48	Yes	0	0	Yes	Acute dilatation of stomach
115	Esophagus implanted into stomach	Stomach only	4	Yes	0	0	Yes	Acute dilatation of stomach
119	Esophagus implanted into stomach	Stomach only	4	Yes	0	0	Yes	Acute dilatation of stomach
868	Esophagus implanted into stomach	Stomach only	2	Yes	0	0	0	Aspiration pneumonia
873	Esophagus implanted into stomach	Stomach only	2	Yes	Yes	0	0	Empyema and pneumothorax
82	Esophagus implanted into stomach	Stomach and esophagus	10	Yes	0	0	0	Aspiration pneumonia
83	Esophagus implanted into stomach	Stomach and esophagus	26	Yes	0	0	0	Aspiration pneumonia
88	Esophagus implanted into stomach	Stomach and esophagus	11	Yes	0	0	0	Aspiration pneumonia
113	Esophagus implanted into stomach	Stomach and esophagus	42	Yes	0	0	0	Distemper
120	Esophagus implanted into stomach	Stomach and esophagus	78	Yes	0	0	0	Ruptured acute gastric ulcer
121	Esophagus implanted into stomach	Stomach and esophagus	8	Yes	0	0	Yes	Aspiration pneumonia

esophagus proper so as to obliterate its lumen. Meyer concluded that this method of anastomosis was technically sound. However, he states that "as to its functional results, ways will have to be found *to avoid strictures.*"

In 1909 Janeway and Green[6, 7] published the results of their experimental attempts at esophagogastrostomy. An intrathoracic anastomosis was performed by means of a specially devised Murphy button. The viscera were united around the button with a continuous suture. Only five of sixty dogs survived this procedure. One year later these authors reported another method of esophagogastrostomy. This consisted in an abdominal approach to the stomach which was mobilized along both curvatures down to the prepyloric region. This was followed by a transthoracic approach and resection of the stomach down to the prepyloric region. The anastomosis between the esophagus and stomach was done in two layers by an end-to-end procedure in which the stomach side was pleated down to the same size as the open end of the esophagus. This method was devised upon the human cadaver. One human being was operated upon in this manner, but died fifty-four hours after operation because of leakage at the suture line. Ten of seventeen dogs on which this operation was performed recovered from the operation, but died due to inanition. This was thought to be caused by pyloric spasm following resection of both vagi and a portion of the cardia. The addition of dividing the pyloric sphincter was followed by good results in subsequent esophagogastrostomy upon dogs.

The most encouraging and brilliant results were those of Omi and Karasawa,[8] published in 1913. Using a three-layer silk technique, they performed end-to-end anastomoses in the esophagus, with seven successes out of nine attempts. A similar technique resulted in three survivals out of five esophagogastrostomies. They did a complete gastrectomy with esophagojejunostomy in eleven animals, and seven of them survived.

Kümmel[9] offered an entirely new operative procedure for cancer of the esophagus in 1922. Following mobilization of the stomach and esophagus, he pulled the entire esophagus from the thorax, bringing the cardia of the stomach behind it. The tumor-bearing area was then excised and an esophagogastrostomy was performed. This procedure was carried out upon two patients and five animals, but all died of rupture of the pleura and hemothorax within twenty-four hours after operation.

The next contribution was that of Miller and Andrus[10] in 1923. After drawing the stomach into the thorax, an esophagogastrostomy was performed. A circular area twice the area of the lumen of the esophagus was excised from the fundus of the stomach. The esophagus and stomach were united by a row of mattress sutures of silk. The anastomosis was kept essentially aseptic by means of temporarily placing

purse-string sutures in the stomach and esophagus. A second layer of continuous Lembert sutures of silk grasping the muscularis of the stomach and esophagus completed the anastomosis. Emphasis was made upon the importance of placing the esophageal sutures into the submucosa. Eighteen dogs were operated upon by this method, four dying within a few hours of shock and hemorrhage. Three other dogs died as a result of the operation, two from leakage of the suture line due to tension, and one from an area of gangrene in the wall of the stomach. Of the eleven dogs which survived the operation, ten died in from three to twenty-four days, one being sacrificed at the end of six months. All were stated to have had intact, functioning suture lines. The occurrence of stricture was not mentioned.

Heuer, Andrus, and Bell[11] made a new approach to the problem in 1925. The principle involved consisted of the transplantation of the diaphragm to a level above the prospective site for resection of the esophagus. At a second stage, the esophagus was resected from within the peritoneal cavity. Nineteen of their first series of twenty-six dogs survived the operation of transplantation of the diaphragm. Six dogs underwent diaphragmatic transplantation and subsequent esophagogastrostomy by the technique of Miller and Andrus. One dog died on the operating table, one died on the seventh day from leakage at the suture line, and four animals recovered. Fifty per cent of the four surviving animals were found to have dense strictures at the site of anastomosis.

Saint and Mann,[12] in 1929, published the results of their work on end-to-end sutures of the esophagus. Their technique consisted of an inner row of inverting mattress sutures placed through the whole thickness of the esophagus and an outer row of a continuous suture involving only the muscularis. In six dogs the cervical esophagus was divided and resutured, all surviving except one in which slough occurred at the suture line. A slight stricture occurred in two dogs. A similar procedure performed upon the terminal esophagus in three dogs showed a satisfactory suture line although empyema developed in two of the animals. Three or four dogs in which a small portion of the cervical esophagus was resected obtained a perfect result from an end-to-end anastomosis. One died of leakage at the suture line. When a similar procedure was carried out upon the thoracic esophagus, three out of five dogs had perfect results, one dying from leakage following sloughing of the suture line, and one from intrathoracic hemorrhage.

The most recent experimental studies on esophagogastrostomy were carried out by Adams, Escudero, Aronsohn and Shaw[13] in 1938. A series of anastomoses between the stomach and the esophagus was carried out in thirty-one dogs. In all but five of the experiments, the approach was made through the thorax; from 2.5 to 10 cm. of the

lower portion of the esophagus was resected, and in all but the first two operations a two-layer interrupted linen suture technique was used. Three of six dogs in which portions of the esophagus and cardia were resected died from leakage at the line of suture. Excessive vomiting was noted among the surviving animals, and this was attributed to injury to the vagus nerve. When a similar procedure was used but the anastomosis made to the fundus of the stomach rather than to the cardia, all of five animals died. In this group, one died from shock, one from pneumonia, two from leakage at the line of suture, and one from infection and open pneumothorax. The combined abdominothoracic approach used in this series was felt to have contributed toward the poor results obtained. Leakage at the site of anastomosis occurred in four of thirteen dogs in which an end-to-side anastomosis between the esophagus and the fundus of the stomach was carried out. This was ascribed to the use of a cutting needle in each case Of the nine dogs in which leakage did not occur, two died of pneumonia on the second and fifth days after operation. The seven surviving animals all showed no stricture and a well-healed suture line. In a final group of seven dogs the operation was divided into two stages. A portion of the stomach was delivered through and sutured to the diaphragm at the first stage, to be followed later by resection of a portion of the esophagus and esophagogastrostomy. The presence of granulation tissue caused considerable difficulty, and tension on the suture line was difficult to avoid in view of the firm character of the tissues. Of the seven dogs operated upon, three died of leakage at the suture line, one of aspiration of stomach contents, and one of massive pleural exudate. The remaining two dogs were living and well. The authors concluded that tension was the greatest cause for failure of the suture line to hold, and that a two-layered interrupted linen suture technique was the one of choice since no stenosis resulted from its use.

ANIMAL EXPERIMENTS

The experimental work consisted in operations performed on six series of dogs. In each series a different technique was employed in the performance of an esophagogastrostomy. The fundamental emphasis of the experiments is upon the relative tendency of the different techniques toward perforation at the line of anastomosis between the stomach and the esophagus and toward stricture formation at this site.

Methods.—Fifty-two stock adult dogs were used. Prior to operation the animals were kept upon a diet of soft dog food for four days. On the day of operation the stomach was thoroughly lavaged and the stomach tube left in place until just prior to the division of the esophagus. Morphine sulfate, gr. ½, and atropine sulfate, gr. $\frac{1}{150}$, were administered hypodermically one hour before the operation was begun. Intravenous nembutal in the amount of 1 c.c. per 5 pounds of body weight was given in a leg vein, and after the thorax was opened, oxygen was given

by the intratracheal method under positive pressure throughout the remainder of the operation. Exposure was obtained in every instance by an approach through the eighth intercostal space. Resection of a rib was necessary only in a few animals in which there was marked angulation of the ribs. A transthoracic exposure of the esophagus was utilized in all the animals. The left half of the diaphragm was immobilized in each instance by crushing the left phrenic nerve just before it entered the diaphragm.

The pleura overlying the left lateral aspect of the esophagus was incised longitudinally just above the hiatus and the left vagus nerve was freed from the esophagus. The right vagus nerve was freed in a similar manner. The terminal portion of the esophagus was isolated by blunt dissection and a piece of cotton tape passed around it. The lower 10 cm. of the esophagus were now mobilized. The pleura was incised around the remaining portion of the hiatus and the dissection carried down to the peritoneum. After incision of the peritoneum about the hiatus, the esophagus could be readily stripped from its hiatal connections as far as each vagus nerve. In some instances the vagus nerves were dissected away from the esophagus; in others they were divided. Following this procedure the cardia was found to be quite free, and with the ligation of a few small vessels along both curvatures of the stomach, two-thirds of the stomach could be readily drawn up into the thorax. Following this mobilization, the lungs were packed away with moist gauze, and resection of portions of the lower third of the esophagus was performed, followed by the different types of anastomosis. The cardia was closed by a Parker-Kerr stitch of catgut, and over this a Cushing stitch of silk was applied. The anastomosis was made to the fundus of the stomach in every case. Upon completion of the anastomosis the diaphragm was split from the esophageal hiatus anteriorly for a distance of 10 cm. The anastomosis was allowed to retract up into the thoracic cavity prior to the application of any sutures by which the stomach or esophagus was anchored to the chest wall and prior to the suture of the diaphragm to the stomach wall. As will be brought out subsequently in this report, attempts to diminish tension on the line of anastomosis were made by anchoring the stomach and the esophagus to the chest wall.

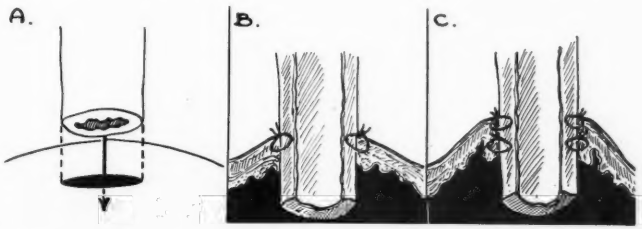

Fig. 1.—Procedure used in Series 1. The open end of the esophagus was introduced into the stomach through a slit in the fundus. The first row of Lembert sutures of silk is shown in *B*, and it has been inverted beneath a second row of similar sutures in *C*.

Silk sutures were used for this purpose. These grasped the submucosa of the hollow viscera and the periosteum of a nearby rib or the intervertebral disk. Two such sutures were placed in each viscus, one above the other as shown in Fig. 12. The chest was closed without drainage. Any air remaining in the pleural cavity was removed by aspiration. Intravenous and subcutaneous fluids were given for the first seventy-two hours after operation. Small amounts of fluid were given by mouth during the second and third postoperative days. The animals were fed soft dog

food from the third to the tenth day after operation, and a full diet, including bones, was given thereafter. Fluoroscopic examination of the esophagus and stomach was carried out at intervals after operation. The last thirty dogs in this series were esophagoscoped from time to time.

Series 1.—The object of this series was to study the healing in and the end results of an esophagogastrostomy in which the end of the esophagus was introduced *into* the stomach through an opening in the fundus. From 3 to 6 cm. of the terminal esophagus were resected and the open end of the esophagus was introduced into the stomach for a distance of 2 to 4 cm. through an incision in the fundus. A row of interrupted Lembert sutures of silk united the stomach and esophagus. These sutures grasped the submucosa of both viscera. A second row of Lembert sutures pulled the stomach up around the esophagus (Fig. 1). The stomach alone was anchored to a

TABLE II

DOG NO.	DURATION OF LIFE AFTER OPERATION (DAYS)	PERFORATION	STRICTURE	CAUSE OF DEATH
		Series 1A		
Operation: Esophagogastrostomy in which the distal 4 cm. of esophagus was introduced into the stomach through an incision in the fundus. In addition, sutures anchoring only the stomach were used.				
89	2	None	Acute*	Acute dilatation of the stomach
108	48	None	Delayed† (treated)	Acute dilatation of the stomach
115	4	None	Acute	Acute dilatation of the stomach
119	4	None	Acute	Acute dilatation of the stomach
868	2	None	Acute	Aspiration pneumonia
873	2	Yes	Acute	Empyema and pneumothorax
Incidence of perforation, 16⅔%; incidence of stricture, acute type, 83⅓%; delayed type, 16⅔%; total, 100%.				
		Series 1B		
Operation: Same as 1A, with the addition of sutures anchoring the stomach and esophagus.				
82	10	None	Delayed	Aspiration pneumonia
83	26	None	Delayed	Aspiration pneumonia
88	11	None	Delayed	Aspiration pneumonia
113	42	None	Delayed (treated)	Distemper
120	78	None	Delayed (treated)	Ruptured gastric ulcer
121	8	None	Acute	Aspiration pneumonia
Incidence of perforation, 0%; incidence of stricture, acute type, 16⅔%; delayed type, 83⅓%; total, 100%.				

*By the term acute stricture, we mean the acute obstruction of the gastro-esophageal stoma caused by the intragastric portion of the implanted esophagus inverting back into the esophagus proper and becoming incarcerated and acutely edematous. The portion of the esophagus which projects into the lumen of the stomach is probably forced back into the lumen of the esophagus by the peristalsis in the stomach itself. After being inverted into the esophagus, the stump becomes edematous and is thus incarcerated. It is usually dark red or black and very edematous and impossible to reduce. (See Fig. 2.)

†Delayed stricture is a term used to describe the occlusion of the stoma by the growing together of the raw edges of implanted esophagus so as to form a membrane between the esophagus and the stomach. Inasmuch as this type was not noted to occur until six to eight days postoperatively, this kind of stricture has been called delayed in contradistinction to the acute form which was found to occur two to four days after operation. The obstructive symptoms in some of these dogs were palliated by periodic esophagoscopy and dilatations. (See Figs. 3, 4 and 5.)

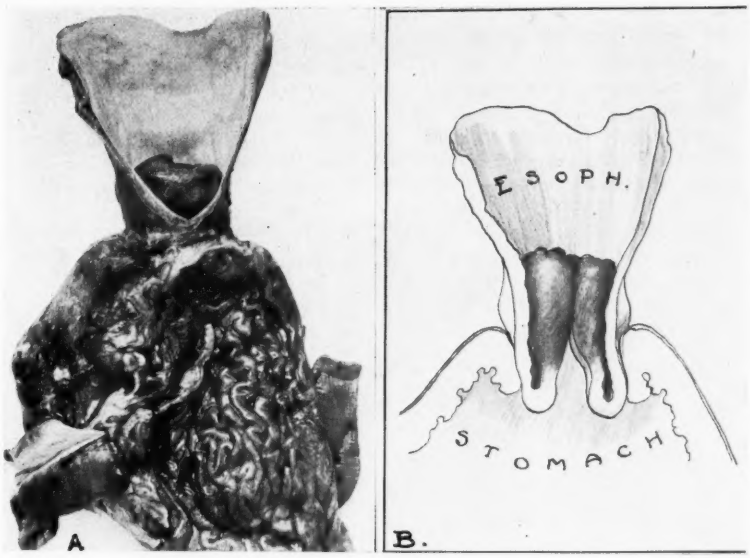

Fig. 2.—*A*, Acute stricture found at autopsy on the third postoperative day. Note the dark, edematous mass of inverted esophagus which completely blocks the stoma. *B*, Sketch to show the inversion of the implanted esophagus through the stoma and into the esophageal lumen.

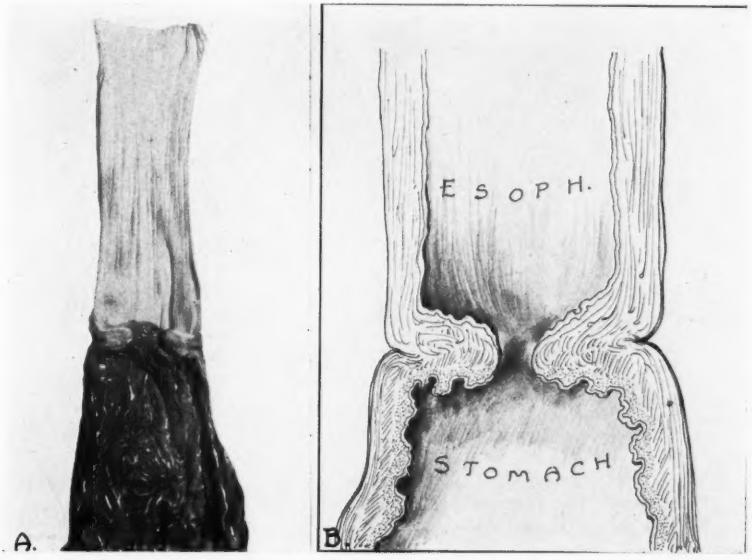

Fig. 3.—*A*, Delayed stricture found at autopsy on the fourteenth postoperative day. The raw edges of the implanted portion of the esophagus have healed together, forming a tough membrane on one side, with stomach mucous membrane on the other. *B*, A detailed sketch of a delayed stricture.

rib or vertebral body in one series and both stomach and esophagus were anchored in the other. The results are set forth in Table II.

Discussion.—The results of this set of experiments demonstrate clearly that this type of anastomosis is uniformly followed by stricture. This conclusion was borne out clinically in the two patients in which this type of esophagogastrostomy was done, for both of them developed stricture. When the stomach alone was anchored, the "acute" stricture resulted regularly, whereas when both stomach and esophagus were anchored, the delayed stricture was found in every case but one. Several of the

Fig. 4.—Delayed stricture which was discovered at autopsy on the sixteenth postoperative day. The end of the pointer is in the tiny opening which is all that remains of the original stoma.

animals were esophagoscoped at intervals after operation in an attempt to explain this phenomenon. The free end of the implanted esophagus was found to invert upon itself with equal ease where either type of anchoring suture had been used. We would surmise that when only the stomach is anchored, incarceration of the inverted esophagus occurs because of tension on it, whereas if both stomach and esophagus are anchored, there is no tension, the inverted esophagus can straighten out again, and the edges eventually heal together, thus causing the "delayed" stricture.

Another possible explanation is that the anchoring sutures in the esophagus interfere with peristalsis in the esophagus and thus prevent the inverted stump from being caught in the esophageal lumen.

This type of anastomosis has been advocated by Sauerbruch,[4] Willy Meyer,[5] Bengolea,[14] and Fischer.[15] Bird,[16] after an extensive review of the literature commenting on this type of esophagogastrostomy, states: "Because of the relative safety of this method, which can be made aseptic, it probably is to be preferred over methods of direct suturing such as that of Adams and Phemister." We believe that this method should *not* be employed because of the high incidence of stricture which follows its use.

Fig. 5.—Microscopic section through a delayed stricture (×7). Note that the intragastric portion of the esophagus has not sloughed away. The gastric mucosa has grown over one aspect of the stricture, while the original mucous membrane of the esophagus remains on the upper aspect.

As will be seen from the subsequent protocols, this method of esophagogastrostomy is no safer than the end-to-side anastomosis from the point of view of perforation, provided anchoring sutures are used in the stomach and esophagus.

Series 2.—The purpose of this group of experiments was to investigate the results of an esophagogastrostomy in which the end of the esophagus was anastomosed to the edges of a circularly excised area in the fundus of the stomach. The type of anastomosis was an end-to-side suture. The first layer of sutures united the whole thickness of the stomach and the esophagus. In some instances a continuous suture of catgut, interrupted at the quadrants by single sutures of silk, was used, and in others interrupted sutures of silk were employed. No differences in healing or in stricture formation were noted when either of these types of sutures was used.

TABLE III

DOG NO.	DURATION OF LIFE AFTER OPERATION (DAYS)	COMPLICATION		CAUSE OF DEATH
		PERFORATION	STRICTURE	
Series 2A				
Operation: Esophagogastrostomy in which the end of the esophagus is anastomosed with the edges of a circularly excised area on the fundus of the stomach. In addition, sutures anchoring only the stomach were used.				
19	85	0	0	Inanition (constriction of stomach by diaphragm)
25	7	Yes	0	Empyema and pneumothorax
29	26	0	0	Pneumonia (constriction of stomach by diaphragm)
32	3	Yes	0	Empyema
33	14	0	0	Atelectasis; vegetative endocarditis
35	100 (living)	0	0	Living
38	3	Yes	0	Perforation
55	5	0	0	Distemper
Incidence of perforation, 37½%; incidence of stricture, 0%.				
Series 2B				
Operation: Same as Series 2A, with the addition of sutures anchoring both the stomach and esophagus.				
9	10	0	0	Distemper
43	149	0	0	Distemper
44	16	0	0	Acute liver necrosis; sulfapyridine given
49	9	0	0	Distemper
50	29	0	0	Distemper
56	11	0	0	Distemper
57	50	0	0	Distemper
Incidence of perforation, 0%; incidence of stricture, 0%.				

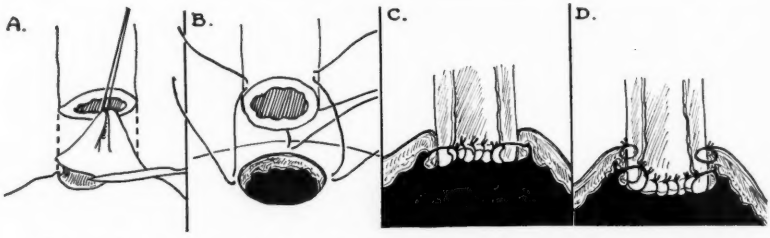

Fig. 6.—Procedure used in Series 2. *A*, A circular area equal in size to the lumen of the esophagus was excised from the fundus of the stomach. *B*, An end-to-side anastomosis was then done. *C*, The inner row of through-and-through sutures. *D*, Outer row of Lembert sutures of silk inverted the first row.

The second row of sutures consisted of Lembert stitches of silk which involved the submucosa of both organs (Fig. 6). In one series the stomach alone was anchored to the chest wall, and in the other both stomach and esophagus were so anchored. The results are shown in Table III.

Discussion.—There was no instance of stricture following any of the operations performed in the fifteen dogs in this series. Perforation occurred three times in the series of eight dogs in which only the stomach had been anchored, but did not occur in any of the seven dogs in which both stomach and esophagus had been anchored. The technical results in the remaining twelve dogs were essentially successful. The healing between the stomach and the esophagus was excellent (Figs. 7 and 8). Two of the animals died as a result of constriction of the stomach by the diaphragm after operation. This complication resulted from the type of operation which was used at the beginning of the experiments, wherein the hiatus was not enlarged before suturing it to the stomach.

There was a definite increase in contamination of the pleura with this type of opening made in the stomach. Technically, it is more difficult to control soiling where a circular area is excised from the stomach than where a simple incision is made. Evidence of some soiling was shown by temperature elevations of from 2 to 4° F. from seven to ten days after operation and in moderate-sized pleural effusions which necessitated aspiration.

Fig. 7.—The line of anastomosis sixty days after operation. Note the excellent healing at the junction of stomach and esophageal mucous membrane.

Series 3.—The purpose of the experiments on this series of six dogs was to determine the end results of an esophagogastrostomy which was in all respects similar to that in Series 2, except that the esophagus was anastomosed to the edges

of a simple transverse incision in the fundus of the stomach (Fig. 9). In all animals both the stomach and esophagus were anchored to the chest wall. The results are shown in Table IV.

Fig. 8.—Photograph of a specimen removed sixty days after operation. Perfect healing has taken place between the stomach and esophagus.

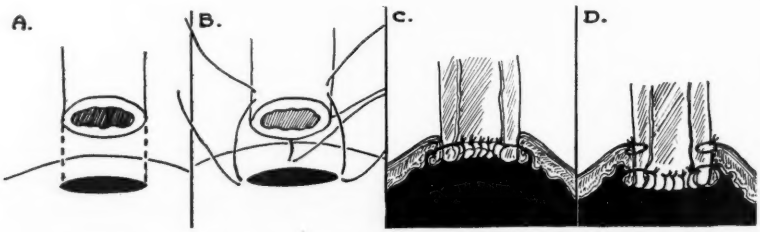

Fig. 9.—Procedure used in Series 3. This is identical to that used in Series 2 (Fig. 6), except that the end-to-side anastomosis is done between the open end of the esophagus and a linear slit rather than to a circularly excised area in the stomach.

TABLE IV

DOG NO.	DURATION OF LIFE AFTER OPERATION (DAYS)	COMPLICATION			CAUSE OF DEATH
		PERFORATION	STRICTURE	MISCELLANEOUS	
Series 3A					
Operation: Esophagogastrostomy in which the end of the esophagus is anastomosed with the edges of a slit made into the fundus of the stomach. Anchoring sutures to the stomach and esophagus were utilized.					
62	45	0	0	0	Pneumonia and lung abscess
63	49	0	0	0	Pneumonia
67	8	0	0	0	Distemper
68	20	0	0	0	Distemper
69	85	0	0	0	Distemper
830	75	0	0	Gastric ulcer; diaphragmatic hernia	Diaphragmatic hernia
Incidence of perforation, 0%; incidence of stricture, 0%.					

Discussion.—The results shown from this type of operation when used upon six dogs would indicate that this is an acceptable type of operation in that successful technical results were obtained in all of the dogs in this series. No perforations occurred in this series, nor was stricture encountered following its use. This procedure is more rapid and can be done with greater ease as regards avoidance of pleural contamination than when a circular area is excised from the fundus of the stomach. This type of anastomosis combined with the anchoring of the stomach and esophagus appeals to us as being the most satisfactory from all viewpoints. The fatal pneumonias and distemper were secondary to a laboratory epidemic.

Series 4.—The purpose of the experiments performed on this group of dogs, which includes all of the fifty-two animals operated upon, was to determine the effect of tension on the line of suture and to devise methods to combat such tension. Anastomoses were performed according to the various techniques described in Series 1, 2, and 3. In some of the animals no anchoring sutures were used; in others the

TABLE V

ANCHORAGE	DOG NO.	TOTAL DOGS	NO. OF PERFORATIONS	INCIDENCE OF PERFORATIONS (%)
None	2 75 87 70 80 94 72 86 97	9	8	89
Stomach only	19 35 115 25 38 119 29 55 868 32 89 873 33 108	14	4	29
Stomach and esophagus	9 67 126 42 68 129 43 69 131 44 82 135 49 83 136 50 88 139 56 113 148 57 120 153 62 121 830 63 125	29	0	0

stomach alone was anchored, and in others both stomach and esophagus were anchored. The results are shown in Table V.

Discussion.—The results of this set of experiments were very striking in that, where no anchoring sutures were used to relieve tension, the percentage of perforations was 89; where the stomach alone was anchored, thus relieving some tension, the percentage of perforation was 29, and where both stomach and esophagus were anchored, there were no perforations. This would seem to indicate that tension plays a major part in the production of perforations and that the relief of tension by the anchoring sutures is a step of real importance in the performance of an esophagogastrostomy.

The fate of the anchoring sutures has been followed with interest. Those in the stomach have been intact at autopsy in all cases. About one-half of those in the esophagus have been found intact; one-half have been discovered still attached to the esophagus, but they had pulled away from the chest wall for a short distance, bringing with them a coarse strand of fibrous tissue. No instances of traction diverticuli have been encountered. This band of fibrous tissue, however, was still holding the esophagus to the chest wall. The role of the anchoring sutures in the esophagus is probably a dual one in that they relieve tension at least long enough for healing to take place and in that they may break the force of the peristaltic waves, thus protecting the suture line.

It is our belief that the use of these anchoring sutures is one of the important contributions of this experimental work.

Series 5.—This series, which is in reality a summation of some of the other series, was studied in order to determine the incidence of stricture following the various types of anastomosis. Table VI shows the results in this series.

TABLE VI

METHOD	DOG NO.	TOTAL DOGS	NO. OF STRICTURES	INCIDENCE OF STRICTURES (%)
Implantation of esophagus into stomach	82 108 120 83 113 121 88 115 868 89 119 873	12	12	100
End-to-side anastomosis to a circularly excised area	2 42 86 9 43 87 19 44 94 25 49 97 29 50 125 32 55 126 33 56 129 35 57 131 38 80	26	0	0
End-to-side anastomosis to an incised area	62 69 148 63 135 153 67 136 830 68 139	11	0	0

Discussion.—In our experience, all the operations in which the end of the esophagus was implanted into the lumen of the stomach were followed by stricture, either acute or delayed. In the small series of three dogs in which this type of anastomosis was carried out and in which no anchoring sutures were used, perforations occurred in all three. These were thought to have been due to the violent peristalsis resulting from the blockage of the lumen of the esophagus by the stump

inverting into the lumen of the esophagus. It is logical to assume that any interference with the patency of the esophagus after operation will result in vigorous peristalsis in the esophagus, and this in turn will throw added strain upon the suture line. Unless the edges of the esophagus are united accurately to the edges of an opening in the stomach, they retract and heal together, thus forming a dense stricture which is covered below with mucous membrane of the stomach and above by mucous membrane of the esophagus.

No strictures resulted from any one of the thirty-seven esophagogastrostomies in which the end-to-side type of anastomosis was performed. These animals have been followed for as long as six months after operation. The stomach and the esophagus united smoothly and firmly, both on the mucous membrane side and on the exterior.

Series 6.—After we had had the experience of operating upon forty-two dogs on which different types of esophagogastrostomy had been performed and various types of anchoring sutures used, it was decided to perform what we considered the two most preferable operations upon ten dogs. In one group of five dogs an end-to-side anastomosis was performed between the esophagus and the edges of a circularly excised area in the fundus of the stomach. Interrupted sutures of silk uniting the

TABLE VII

DOG NO.	DURATION OF LIFE AFTER OPERATION (DAYS)	COMPLICATION		CAUSE OF DEATH
		PERFORATION	STRICTURE	
		Series 6A		
Operation: Resection of lower 6 to 8 cm. of esophagus and 10 cm. of cardia, with subsequent esophagogastrostomy in which the end of the esophagus is anastomosed with the edges of a circularly excised area. Anchorage sutures to stomach and esophagus were utilized.				
42	17	0	0	Distemper
125	110 (living)	0	0	Living
126	40 (living)	0	0	Living
129	107	0	0	Distemper
131	8	0	0	Ruptured spleen
Note: Dogs operated upon by this method showed evidence of more pleural soiling than those in Series 4B, in that they all ran a temperature of 2 to 3° above normal for the first five to eight postoperative days, three having definite pleural effusions.				
		Series 6B		
Operation: Same as Series 6A, except that the end of the esophagus was anastomosed to the edges of the slit made into the fundus of the stomach. Anchorage sutures to both stomach and esophagus were utilized.				
135	92	0	0	Diaphragmatic hernia; healing gastric ulcer
136	23	0	0	Lung abscess; acute necrosis of liver; sulfapyridine
139	82 (living)	0	0	Living
148	76 (living)	0	0	Living
153	74	0	0	Acute dilatation of stomach; gastric ulcer
Note: No dog in this series ran a temperature more than 1.5 degrees above normal during the first week postoperatively. Those dogs which have been autopsied in this series show markedly fewer postoperative adhesions in Series 6B, than those in Series 6A.				

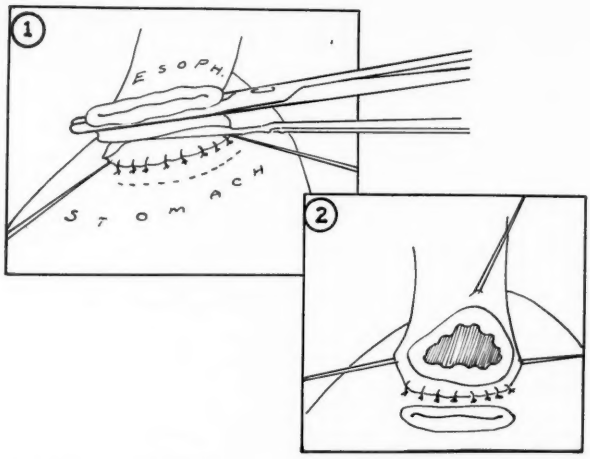

Fig. 10.—*1*, The esophagus has been resected between clamps, the proximal one of which has been left in place. A row of Lembert sutures of silk which penetrate the submucosa unite the stomach and the esophagus.

2, An incision has been made into the fundus of the stomach and the esophagus divided just proximal to the clamp.

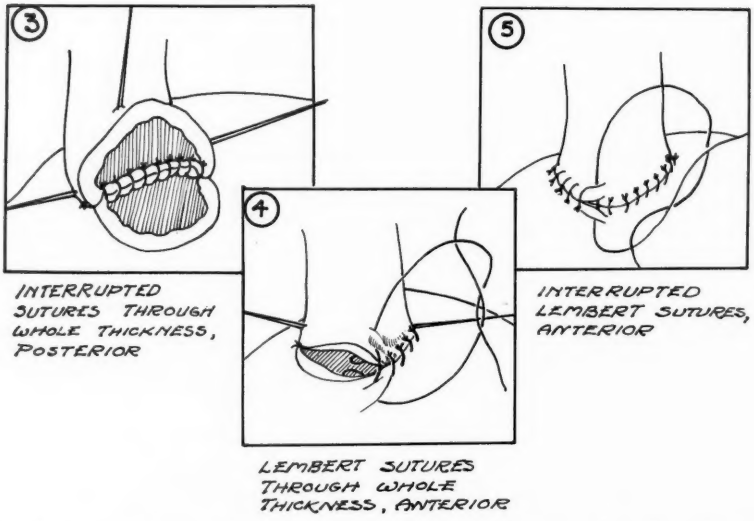

Fig. 11.—*3*, Interrupted sutures of silk unite the stomach and the esophagus posteriorly. This is the second row of posterior sutures, and it involves the whole thickness of the cut edges.

4, The first row of anterior sutures consists of Lembert sutures of silk and involves the whole thickness of the stomach and esophageal wall.

5, A row of Lembert sutures of silk complete the anastomosis. It involves the submucosa of both organs.

whole thicknesses of the walls of both organs were used for the first row of sutures. The second row consisted of Lembert sutures of silk. Both the stomach and esophagus were anchored to the chest wall. In another group of five dogs the above operation was carried out in every detail except that the end of the esophagus was anastomosed to the edge of a transverse incision in the fundus of the stomach. The results are shown in Table VII.

Discussion.—This final series of operations was carried out for the purpose of proving to our own satisfaction the results of what was considered to be the most effective type of operation. This procedure is shown in accompanying illustrations (Figs. 10, 11, and 12) and may be briefly described as follows: The exposure and mobilization of the stomach and esophagus are carried out as described above under the section on Experimental Methods. The operative area is well packed off with moist gauze. Transection of the esophagus 8 to 10 cm. above the cardia is performed between clamps, and the cut edges are treated with phenol and alcohol. A moist sponge is then placed about the esophageal stump in order to protect the pleural cavity. The stomach is transected between clamps so as to excise the upper 10 cm. of

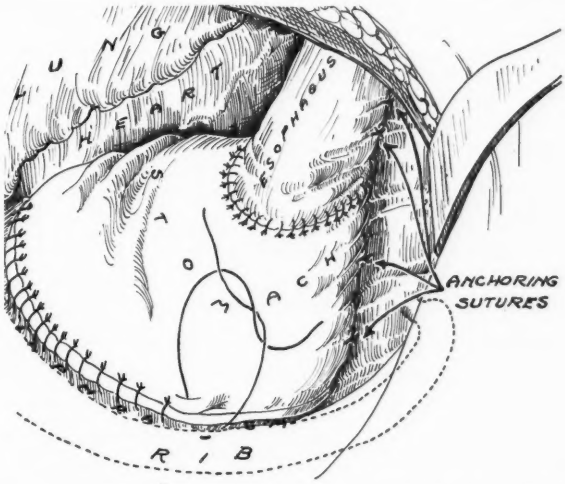

Fig. 12.—The anastomosis has been completed. The united organs have been allowed to retract to a level at which there is no tension and have been anchored at that point by sutures of silk. The diaphragm has been sutured well down on the stomach so as to avoid a drag on the line of anastomosis.

cardia, together with a fair portion of the gastrohepatic ligament. Phenol and alcohol are again utilized prior to the inversion of the cut end of the stomach. An area on the medial portion of the anterior surface of the stomach is then chosen for the proposed site of the anastomosis. The esophageal stump, still closed by a clamp, is then drawn downward and united to this area of the stomach by guide sutures placed at each lateral extremity of the esophagus. This maneuver is carried out to make the length of the incision into the stomach approximately equal to the diameter of the esophagus. Interrupted sutures of silk which involve the serous, muscular, and submucosal layers of the stomach and the muscular and submucosal layers of the esophagus are then placed between these guide sutures, thus completing what will eventually be the outer posterior layer of the anastomosis. An incision is made into the fundus of the stomach, the submucosal vessels having been clamped and ligated

prior to incision through the mucosa. The esophagus is now divided just above the clamp. No attempt is made to stop bleeding points in the freshly cut end of the esophagus. The posterior inner layer of interrupted silk sutures is then placed. These sutures involve the whole thickness of the walls of the stomach and esophagus, the knot being tied on the inside. An anterior inner layer of Lembert sutures of silk involving the whole thickness of both viscera is now placed with the knots tied on the outside. An anterior outer layer of interrupted Lembert sutures of silk similar in every respect to the outer posterior layer completes the anastomosis. All sutures placed in the esophagus are inserted in the direction of its long axis so as to interfere with the blood supply as little as possible. The anastomosis is allowed to seek its desired position in the thorax, namely, that position of least esophageal tension. Two anchoring sutures are then placed in the esophagus 3 to 4 cm. above the anastomosis, as described in Experimental Methods. Similar sutures are placed so as to approximate the stomach 2 to 4 cm. below the anastomosis to the nearest intervertebral disk medially, and laterally to the periosteum of the seventh or eighth rib. These sutures are placed so that the intervening esophagogastrostomy is freely movable and not under tension. The diaphragmatic edges are approximated as low down upon the stomach wall as possible. During this diaphragmatic approximation, emphasis is laid upon not allowing this maneuver to produce tension upon the anastomosis above. Tension is evidenced by both palpation and direct vision, as well as by localized cyanosis of terminal portions of the esophagus. In our experiments we did not utilize the omentum as an additional protective layer to the anastomosis. This would appear to be an advisable procedure. It was not used by us because we were desirous of a fatal result in case of perforation, however small. The operation was concluded as described in Experimental Methods.

All ten animals survived their operations and no perforations nor strictures resulted. We again noted the greater technical difficulty involved in the excision of a circular area of the stomach and the greater pleural reaction following such an operation.

COMMENTS

During the progress of our experimentation, approximately equal numbers of operations were carried out with continuous or interrupted sutures being used for the inner layer of the anastomosis. The continuous sutures were interrupted at the halves or the quadrants of the stoma by a suture of silk placed at those points. The results showed no striking difference. All that can be said is that the clinical impression was gained at the time of operation that there was less interference of blood supply when interrupted sutures were used. Catgut or silk technique was used interchangeably for this inner row of sutures, without noticeable differences in operative results.

Postoperative vomiting occurred frequently after any type of esophagogastrostomy as long as soft foods were used. In practically all dogs the addition of bones to the diet caused cessation of vomiting. The slower and more complete mastication is suggested as an explanation of this reaction. In those dogs in which a circular area was excised from the fundus of the stomach prior to anastomosis, a greater tendency toward the reflux of barium from the stomach into the esophagus was noted for thirty to fifty days after operation. In many

of such animals the regurgitation could be produced by maintaining the animal in a high Trendelenburg position for a few minutes. This could not be produced after the fiftieth postoperative day.

Diaphragmatic hernia, which has occurred twice in these experiments, was secondary in each instance to improper closure of the diaphragm. Acute dilatation of the stomach occurred frequently in association with the presence of stricture and was often fatal because of displacement of the intrathoracic viscera. This occurred three times without the presence of stricture, but in each instance was recognized and treated successfully without recurrence. The usual dangers of intrathoracic surgery were encountered frequently, namely, atelectasis and pneumonia. A lobar type of pneumonia occurred in twelve instances, responding well to sulfapyridine therapy, except in the two instances of an acute liver necrosis which occurred after prolonged intake of the drug. A rare postoperative complication, namely, acute vegetative endocarditis, which was on an auricular septum defect, with the primary site of infection in a consolidate lung, was encountered once. The frequent incidence of distemper parallels that encountered in our laboratory during the year.

We are unable to explain definitely the difference in the type of stricture encountered during the implantation type of operation following the anchoring of one or both viscera. The suggestion is made that the explanation may lie in the difference in the degree of tension as well as a variance in the amount of esophageal peristalsis. The occurrence of perforation has been influenced in our experience by the amount of tension upon the anastomosis. An adequate circulation at the site of anastomosis appears to be obtainable when this factor is controlled. Sutures anchoring both organs to firm thoracic structures have controlled this factor in our experiment. Sutures only involving the pleura tear out easily and do not accomplish the necessary anchorage.

CONCLUSIONS

Fifty-two dogs were used in a study of the operation of esophagogastrostomy. Special emphasis was placed upon the occurrence of perforation at the suture line and upon the frequency of stricture secondary to different types of anastomosis of the esophagus to the stomach.

Stricture occurred in every case in which the end of the esophagus was implanted into the stomach. No stricture followed the end-to-side type of anastomosis when the end of the esophagus was anastomosed either to the edges of an incision in the fundus of the stomach or to the edge of a circularly excised area of the fundus.

The incidence of perforation at the line of anastomosis was 89 per cent when no anchoring sutures were placed in the stomach or esophagus; 29 per cent when such sutures were placed in the stomach alone; and 0 per cent when they were placed in both the stomach and esophagus.

The use of anchoring sutures in the stomach and esophagus to relieve tension on the suture line is a most important technical step in the performance of an esophagogastrostomy.

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DISCUSSION ON "SURGICAL ASPECTS OF CARCINOMA OF THE ESOPHAGUS: REVIEW OF THE LITERATURE AND REPORT OF FOUR CASES" BY DR. ALTON OCHSNER AND DR. MICHAEL DE BAKEY;* AND "EXPERIMENTAL ESOPHAGOGASTROSTOMY" BY DR. B. NOLAND CARTER, DR. JEAN STEVENSON, AND DR. OSLER A. ABBOTT

DR. JOHN H. GARLOCK, New York.—It is too bad that Dr. DeBakey was unable to read his entire paper, because it is a scholarly presentation of the subject of carcinoma of the esophagus.

*See page 401 for article by Ochsner and DeBakey.

As you know, it has been convenient to discuss carcinoma of the esophagus with respect to three portions of the organ—the cervical portion, the midthoracic third extending from the upper border of the arch of the aorta, and the lower third. We are concerned today with the lower two-thirds of the esophagus.

Although the ideal procedure would be one establishing esophagogastric continuity in those lesions involving the central portion of the esophagus, it is impossible to do so and effect a radical cure. When the new growth is located in the lower third of the organ or arises at the cardiac end of the stomach and secondarily produces esophageal obstruction, conditions are ideal for re-establishing continuity between the esophagus and stomach.

We have made it an important point to differentiate histologically (by esophagoscopic biopsy) carcinomas of the squamous cell type as opposed to carcinomas of the adenoma variety, because I think the operative approach is different. In the majority of the squamous cell carcinomas at the lower end of the esophagus, the lymphatic spread is usually toward the neck. In the adenocarcinomas which originate at the cardia and spread upward toward the esophagus, the lymphatic spread is mostly toward the liver and the gastrohepatic omentum. Therefore, when the microscopic report is adenocarcinoma, we explore the abdomen as a preliminary procedure in order to determine operability, rather than subject the patient to the risk of an unnecessary thoracic exposure.

In the past four years I have explored thirty-four cases of carcinoma of the esophagus, including the squamous cell variety and carcinoma of the cardia. There were twenty-one cases of squamous cell carcinoma, and thirteen were operable, an operability of 62 per cent. Of the thirteen resected cases, eight were subjected to the modified Torek procedure that I have described previously. There were two deaths. Five patients had an intrathoracic esophagogastric anastomosis, with three deaths. The operative mortality was 38 per cent. Of the eight survivors, the first patient died twenty-two months later of a superior mediastinal recurrence; the second, three and one-half months after operation; the third, one year later of generalized metastases; and the fourth, four and one-half months after operation of a recurrence in the posterior mediastinum. Four patients are alive and well today; one, after three and one-half years; one, after fourteen months, with anastomosis; one after ten months, with anastomosis; and one, after three months, with the Torek procedure.

In the group of cases of adenocarcinoma of the cardia, with secondary esophageal obstruction, I have explored thirteen cases and found five operable, an operability of 31 per cent, as compared with 62 per cent in the previous group. Of the five resected cases, all of them having intrathoracic anastomosis, two died, an operative mortality of 40 per cent. Of the three survivors, one is alive and well after eleven months; another is alive and well twenty-four days postoperatively; and the third is alive and doing well, five days after operation. Of the two mortalities, one died of cerebral embolus on the fourth day, and one, a 70-year-old woman, died on the third day of general debility. Autopsy was negative.

In the combined group, we have eighteen patients who were subjected to resection, with an operative mortality of 38.8 per cent.

In re-establishing esophagogastric continuity, we have performed a careful two-layer suture anastomosis between the end of the esophagus and the anterior wall of the upper stomach, using silk throughout. In order to eliminate tension on the suture line and thus prevent disruption, the esophagus is invaginated into the stomach by drawing the stomach upward over the esophagus in a sleevelike fashion. The stomach is anchored with interrupted silk sutures to the cut edges of the mediastinal pleura and also to the enlarged diaphragmatic opening. In those patients who have

succumbed to the operation, varying in time from two to five days after operation, disruption was not a factor in their death. As a matter of fact, the healing was quite solid in each instance. The blood supply of the stomach was intact, despite the fact that, in most of the cases, it was necessary to ablate most of the proximal blood supply in order to obtain sufficient mobilization of the stomach.

The recent interest in the subject of carcinoma of the esophagus has resulted in a rapidly increasing number of successful resections. Cancer of this organ will soon be universally considered as curable, and not, as hitherto classified, "hopeless," to be treated by palliative methods.

DR. W. E. ADAMS, Chicago.—I have enjoyed very much hearing both of these papers, and I am encouraged by the recent interest shown in this subject. That carcinoma of the esophagus is a problem of considerable magnitude is evidenced by its high incidence, ranking fourth in frequency of all malignant tumors in men over 20 years of age (fourth only to cancer of the stomach, lung, and rectum, in that order).

Because of the lateness of the hour, I will only show some slides, to illustrate a few points.

(Slide) I think that, in considering an operation on the esophagus, one of the important things is an adequate exposure. The Japanese emphasize this point in their work and attribute much of their success to the use of a very low pressure anesthesia which they term "open anesthesia." In our operations we have used simple mask anesthesia, with a minimum of pressure in all cases.

(Slide) This illustration will be familiar to many of you, but I show it now to emphasize a technical point. This patient, who was operated on two and one-half years ago, is living and well today. In her case there was involvement of the coronary glands, which were removed at the time of the operation. I agree with the speakers before me that prevention of tension on the suture line is one of the major factors in the success of the operation for the re-establishment of the continuity of the alimentary tract. Dr. Carter has demonstrated that fact very amply and has substantiated the results of our experiments which were of that nature.

You see here the tumor lifted up (slide) and the two-layer suture line interrupted in type. A linen suture was used and the anastomosis was performed as one would do an end-to-side gastroenterostomy or enteroenterostomy. In our cases, tension on the suture line was avoided by bringing the stomach up into the chest and supporting it in this position by a row of interrupted sutures between the wall of the stomach and the diaphragm.

No retention sutures were used in our experimental animals. In this particular case two sutures were placed between the stomach and the pleura. I do not know whether it would always be safe to suture the esophageal wall to the pleura. It may be a good thing to do. However, I have felt that the less one handles the esophagus, the better, for trauma is poorly tolerated by this organ. Another factor of importance concerns the blood supply in this region. Since it is especially poor at the lower end of the thoracic esophagus, leakage from lack of healing at the site of anastomosis is apt to occur if too much of the esophagus is mobilized for the procedure.

(Slide) Here is a post-mortem specimen of a patient who died one week following this operation. There was little evidence of infection in the mediastinum at autopsy and there was no evidence of leakage at the point of anastomosis.

DR. ABBOTT.—In response to the remarks of Dr. Adams in regard to the placing of sutures in the esophageal wall, I thought it would be of interest to make a few

short remarks about the placing of sutures and any complications which we met in that regard.

In animals in which sutures were placed in the esophagus and stomach, the sutures were found intact and in place in the stomach in all cases that I autopsied. In the case of the esophagus, however, about 40 per cent of the sutures were pulled out of the intervertebral disk or periosteum, where they had been placed. However, the suture was still in part of the very dense band of adhesion which fixed the esophagus to that point.

At the outset of our experiments we were also conscious of the possibility of producing traction diverticulas by means of these esophageal sutures. However, no true diverticulas were produced, and in the majority of animals the mucosa was either perfectly smooth or very slightly dimpled.

In all cases in which they were present, diaphragmatic hernias were found to be due to faulty closure of the diaphragm. This could be obviated easily by making the posterior approximation of the diaphragm to the stomach prior to placing the anchoring sutures.

DR. CLARENCE BIRD, Providence, R. I.—I would like to know whether or not Dr. Carter cut the phrenic nerve in his animals. There are apparently two good reasons for doing phrenicectomy. One is that because the vagi have been divided, the stomach tends to dilate after operation. The intrathoracic portion of the stomach has a still greater tendency to dilate if the diaphragm remains active and forms a constricting ring in its center.

The second reason is that the action of the diaphragm may tend to pull apart the anastomosis. May I refer to a letter from Dr. Samuel Marshall of Boston, in which he says that of three esophagogastrostomies he has done, in two he did a phrenicectomy. In the third case, the anastomosis pulled apart, which he thought was due to the fact that no phrenicectomy had been done.

Anchoring the stomach and esophagus to the surrounding fixed tissues may be of tremendous importance, and I am delighted to have had Dr. Carter present that means of preventing tension on the suture line.

DR. CARL EGGERS, New York.—The papers read here this afternoon, the discussion elicited by them, and the reports in the literature dealing with successful resections of the esophagus for carcinoma show increasing interest in the subject. However, the number of patients operated on, as compared with the number afflicted with this disease, is still very small. This is due to three factors: a diagnosis made so late that even an attempt at operation is contraindicated; the pessimism of physicians in general regarding the curability of the lesion and their consequent reluctance to refer their patients to a surgeon; and finally, most surgeons' lack of interest in or courage to perform the operation.

The pioneers in this type of surgery have established the feasibility of the operation. Except in a few instances these surgeons have had to demonstrate their successes on the basis of far-advanced cases, and that is still true today. One must never lose sight of the fact that, in addition to the technical difficulties of the operation, we are dealing with cancer, and that in order to get permanent results, it is necessary to operate at a time when the lesion is still localized. Reliable autopsy reports on patients dying as a result of carcinoma of the esophagus have shown that at least 30 per cent have no demonstrable metastases. This knowledge should encourage surgeons to undertake the operation at a time when complete local removal is still possible.

Progress made during the last few years in anesthesia and chemotherapy has helped a great deal in avoiding serious complications or in minimizing their effects. This is well illustrated by two patients on whom I recently operated. The first one, operated on about six months ago, had a very large adherent tumor which required opening of both pleurae in order to remove it. With the aid of intratracheal anesthesia, the lungs remained inflated, secretion could be removed by suction, and no complication resulted. The second patient was operated on about two months ago, likewise under intratracheal anesthesia. Both pleurae had to be opened. A roentgenologic examination made within twenty-four hours showed both lungs fully expanded. Nevertheless, this patient developed pneumonia on the side operated upon. In his weakened condition this might easily have led to a fatal result, but the administration of sulfapyridine terminated the pulmonary complication in a short time and cure resulted.

Members of our Association should be urged to report all their cases operated upon, in order to stimulate interest in the subject.

LOBECTOMY IN CASE OF INJURY OF THE HILUM OF THE LUNG

Report of Two Cases

Oliver Wm. F. Monod*
Paris, France

IN REPORTING these two cases of emergency pulmonary lobectomies, we wish to bring out that the two surgical interventions were justified and successful only because of the efficient organization of the municipal and hospital services.

In both cases, the operation was simple and easily performed. Their success was due mostly to the speed with which were performed all the steps between the firing of the shot which caused the wound and the beginning of the surgical operation: the police call, transportation of the wounded man by the city ambulance service, medical examination, and the beginning of the operation itself.

In the past two years, we have had occasion to see a large number of traumatic hemothoraces. But of these, only in the following two cases were there indications for surgical attempts to save the patient's life.

Case 1.—Mr. F., aged 25 years, a sturdy young man, was brought to the hospital by the police ambulance on June 10, 1938, at 7:25 P.M. Thirty minutes before he had shot himself right-handed in the precordial area. The patient was in a state of acute anemia due to profuse hemorrhage.

The portal of entry of the bullet was in front of the sternal extremity of the fifth rib. There was no portal of exit. Palpation of the skin of the back revealed the presence of the bullet on the level of the seventh rib, 10 cm. to the left of the posterior median line.

The patient was almost unconscious, cold, and the pulse was extremely weak. The left hemithorax was absolutely flat to percussion, as high up as the clavicle.

The path of the projectile and the knowledge that the wound had been inflicted with the right hand allowed us to eliminate the possibility of a lesion of the heart. In the presence of this lightning-like hemorrhage, and inasmuch as the wound, according to the direction of the path, was apparently located in the region of the pulmonary hilum, an emergency operation was decided upon to check the hemorrhage. The operation was begun at 7:30 P.M., less than thirty-five minutes after the shot was fired.

Operation.—Lobectomy of the left middle lobe was performed. A slight chloroform inhalation was sufficient to produce complete anesthesia.

The incision followed the left fifth intercostal space, from the lowest point of the fifth cartilage to the middle axillary line, thus including the portal of entry,

When this article was received on June 15, 1940, Dr. Monod was serving on the French front, at the head of a "Groupe Chirurgical Mobile" which received emergency cases coming directly from the front lines. Because of the uncertainty of his present whereabouts and the difficulty of communication, proof of this article has not been sent to him.

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*Surgeon in charge of the Fondation Marmottan. The Fondation Marmottan is a hospital exclusively reserved for emergency cases. It receives casualties from street accidents, as well as those brought in by the emergency police squads as a result of attempts at suicides, asphyxiations, burns, etc. The surgical and radiologic teams are ready to operate at any time of the day or night.

which was resected. The anterior 5 cm. of the fifth rib, which had been perforated by the bullet, were removed. As soon as the pleura was opened, a great quantity of liquid spurted forth. When most of this blood had been evacuated, it was possible to observe the following:

1. A perforating wound of the pedicle of the abnormally free left middle lobe. From one of the large blood vessels of this middle lobe, probably the vein, the blood flowed continually. The vessel showed a transverse tear, widely open. It was easy to place a forceps on the pedicle, between the mediastinum and the wound.

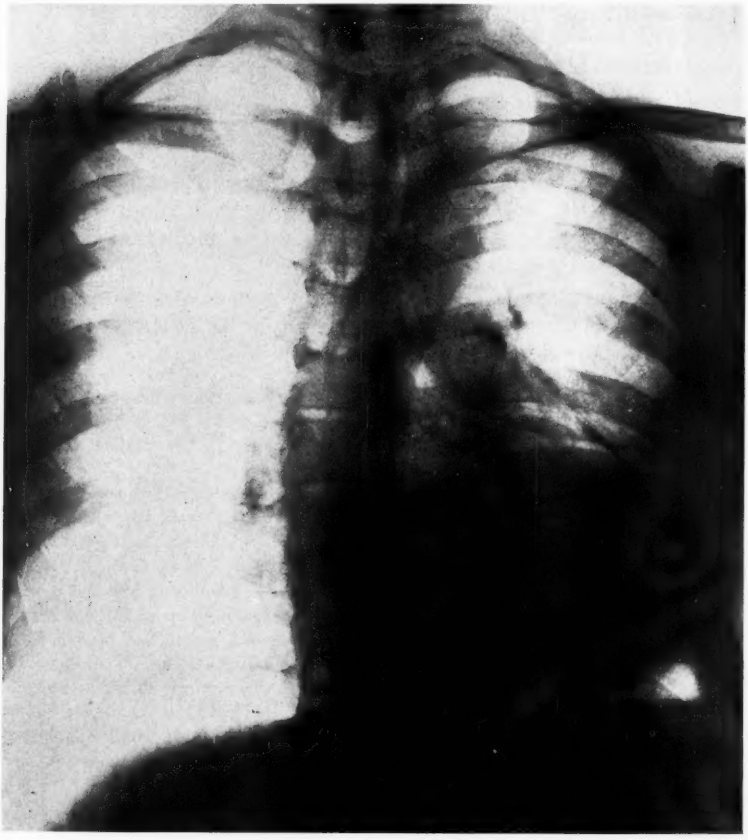

Fig. 1.—Lobectomy of the middle lobe of the left lung, together with the upper portion of the inferior lobe for wound of the pedicle. X-ray taken four months after the operation.

The remaining portion of the lung reoccupies the left hemithorax. A gentle incurving of the superior mediastinum toward the left is seen, as well as a precordial hernia of the right lung into the left pleura. But the pulmonary field and the costodiaphragmatic sinus are transparent. There is no pleural sequela, either plastic or functional. Auscultation is normal. The form and the mobility of the diaphragm are normal by radioscopy.

2. A perforating wound of the apex of the lower lobe; this no longer bled. Within a few minutes, and without any difficulty, an ordinary catgut suture was placed, as a hemostat, on the pedicle of the left middle lobe, which was then

resected. The apex of the lower left lobe was also resected. Hemostasis was effected by two chain stitches of catgut.

Since the patient was young and healthy, and since the lung was in normal condition and contained no foreign bodies, and the operation was performed within a very short time following the wound, it was decided to close the cavity without drainage.

A short incision was sufficient to extract the projectile from the skin of the back (6.35 mm. bullet).

The moment the patient arrived, a transfusion had been ordered; less than ten minutes later the transfusion was being performed (1200 c.c.), and at the same time 500 c.c. of isotonic solution were being injected in the vein of the other arm.

The postoperative course was uneventful. The temperature rose to 38.8° C. two days after the operation, and returned rapidly to normal. A total of 350 c.c. of blood serum was evacuated by three punctures, on the first, second, and fifth days.

On the seventh day, continuous aspiration was established, in order to evacuate the air in the pleura and hasten the re-expansion of the lung. The needle was placed in the second intercostal space in the anterior wall of the thorax. By means of regulated aspiration, it was possible to obtain for five days a depression in the pleura varying between 8 and 15 cm. of water.

Eight days later, the expansion was complete. On the tenth day, the patient began getting up, and shortly after left the hospital. Fluoroscopic examination (Sept. 25, 1938) showed a slight deviation of the mediastinum toward the left and a slight ascension of the left diaphragm, as well as a precordial hernia of the right middle lobe in the left hemithorax.

The patient is now (January, 1940) in sound health and has been found fit for active military service.

One year later, a similar case was admitted to our hospital.

CASE 2.—Mr. B., aged 36 years, was brought in by the police ambulance on May 2, 1939, almost unconscious. Obviously he had a very severe hemorrhage following an attempt at suicide by two revolver shots in the precordial area.

Before removing him from the stretcher, a rapid examination was made; the possibility of heart injury, which had been suggested, was eliminated. We diagnosed a serious wound of the lung, in the hilum area, with the possibility of injury to an intercostal artery. This diagnosis was supported by the fact that the first portal of entry was located one fingerbreadth above the left nipple, and a second one several centimeters below. On palpation, the first bullet could be felt in the fifth intercostal space in the midaxillary line, and the second, under the skin of the back, on a level with the eighth and ninth ribs, 6 to 8 cm. from the posterior median line. The patient had shot himself with the right hand.

Thus, an operation seemed advisable. It was necessary to check if there existed any injury of the heart. The speed of the formation of the hemothorax made us assume that a large pulmonary vessel had been injured. The only means of saving the patient's life was to operate.

We made a rapid fluoroscopic examination. The cardiac shadow was normal, and the heart beats were regular. There was a left hemothorax, without visible air in the pleura. The opacity continued as high as the clavicle.

The shots had been fired shortly after 1:15 P.M. At 1:40, the patient was at the hospital. He was given stimulants, as well as an injection of morphine (10 mg.). As there were no changes in the signs of an acute hemorrhagic anemia we started operating at 2 P.M. As the patient was scarcely conscious, a few whiffs of chloroform on a sponge were sufficient to obtain quiet and relaxation during the operation.

The incision followed the inferior curve of the pectoralis major muscle. The muscle was freed from its points of insertion, from its inferior insertions to the fifth rib. Upon incision into the fifth intercostal space, a terrific gush of blood spurted forth. The pleural cavity was rapidly emptied of the enormous quantity of blood which it contained, revealing injury of one of the main branches of the left superior pulmonary vein.

Fig. 2.—Lobectomy of the superior lobe of the left lung for wound of the pedicle. X-ray taken one year after the operation.

The remaining portion of the lung reoccupies the left hemithorax. A gentle incurving of the superior mediastinum towards the left is seen, as well as a precordial hernia of the right lung into the left pleura. But the pulmonary field and the costodiaphragmatic sinus are transparent. There is no pleural sequela, either plastic or functional. Auscultation is normal. The form and the mobility of the diaphragm are normal by radioscopy.

A subtotal lobectomy of the left upper lobe was performed by mass ligation (with silk), and then the intercostal space was carefully sutured.

The deep surface of the pectoralis major was attached around the line of suture of the fifth intercostal space, and the lower border of the muscle was placed back into this original position. No drainage was instituted.

The pleuropulmonary postoperative course was uneventful. Within a few days, re-expansion of the left lung was complete.

On the fifth day, the bullet in the subcutaneous tissue of the back was removed, and on the seventh day, that in the fifth intercostal space was also extracted (7.35 mm.).

On the twelfth day, an appendectomy was necessary; it was performed under evipan anesthesia, according to the McBurney process. Convalescence was rapid. The patient recovered with practically no sequelae. In January, 1940, he was in perfect condition in all ways.

In these two cases, the indication for surgical procedure was found in the presence of an abundant hemorrhage. The very rapid formation of the hemothorax and its progressive increase left little hope that the patient might spontaneously survive. The operation confirmed the fact that the nature of the lesions excluded hemostasis without intervention.

The operation was performed despite the exclusion of diagnosis of injury of the heart. We presumed that we were dealing with important lesions of the lung in its internal area, with the added possibility of injury of an intercostal artery.

We must note, from an *anatomic* point of view, the existence, in the first case, of a totally free left middle lobe.

From the *technical* point of view, our attention was drawn to the far greater ease of operating on healthy lung tissue. Being resistant and elastic, this tissue permits proper retention of sutures, and the bronchi are easily ligated.

In its postoperative results, we have observed the usefulness of continuous aspiration of the air contained in the pleura, in order to insure the rapid re-expansion of the remaining lung tissue.

We were struck, in both these cases, by the speed of recuperation; there was healing by first intention in from eight and twelve days, without any untoward consequences, thoracic deformation, nor pleural thickening, leaving a regular and mobile diaphragm.

EXPERIMENTAL PNEUMONECTOMY WITH OBLITERATION OF THE BRONCHIAL STUMP

EDWARD S. STAFFORD, M.D.
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BOTH the morbidity and the mortality incident to the surgical removal of all or part of a lung depend largely upon the degree of success attained in closing the bronchus. A number of different methods of bronchial closure have been devised. Nearly all of these have been reviewed by Crafoord.[1] Every surgeon familiar with this problem knows that any of these methods occasionally produces complete healing of the bronchus, but that no method yet described will always be successful. I have devised a method which makes use of certain principles of surgical healing that have not been applied uniformly to this problem. These include approximation without tension, avoidance of strangulating ligatures, and obliteration of the bronchial stump. The criticism will be made justly that success attained by an experimental method upon animals will not necessarily be duplicated in man. This procedure has not yet been carried out upon a patient, but is technically feasible upon fresh cadavers.

A series of thirty-three medium- and large-sized dogs were used in this experiment. Total pneumonectomy was performed on the left side eighteen times and on the right side fifteen times. With ether as the agent, anesthesia was maintained by intermittent positive pressure through a tracheal catheter. An incision is made in the fourth intercostal space about midway between sternum and spine. A rib-spreading retractor affords good exposure. The pulmonary artery is divided and ligated first; next, the pulmonary veins. The bifurcation of the trachea is exposed, care being taken to disturb the fine branches of the bronchial artery as little as possible. Sutures of fine silk are placed about the bifurcation of the trachea so as to approximate the medial wall of the bronchus of the opposite lung to the lateral wall of the bronchus on the operative side. It is necessary to place these sutures before opening the bronchus as dogs will not tolerate an open bronchus for more than a minute or two. These sutures pick up only the outer layers of the bronchial wall, and should not enter the lumen. The lung is amputated by dividing the bronchus in such a manner that a flap is formed from the lateral bronchial wall. A curving bronchial incision is started at the carina and carried diagonally outward and down. Practice enables the operator to judge just how much of the lateral wall of the bronchus is needed to close the defect. The sutures are tied, and additional sutures are placed to restore the continuity of the trachea. When the

From the Department of Surgery, The Johns Hopkins University Medical School.
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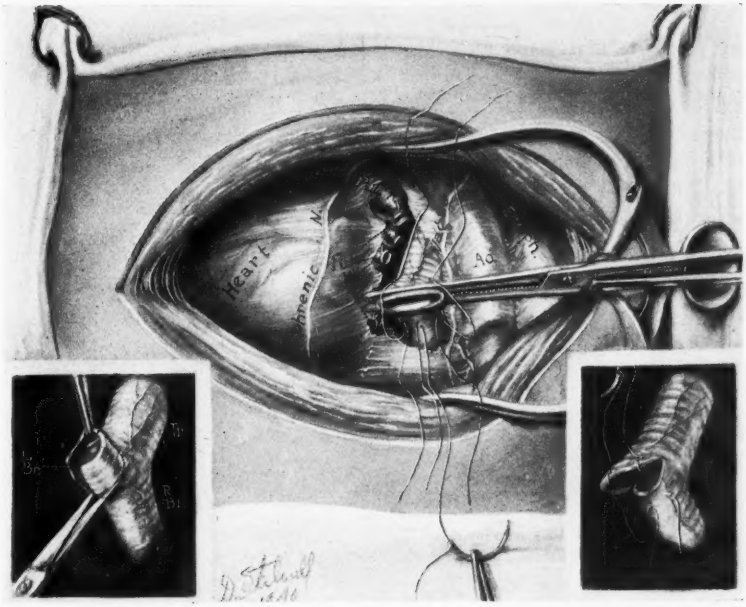

Fig. 1.—Preliminary steps in left pneumonectomy. The pulmonary vessels are ligated, the bifurcation of the trachea is exposed, and sutures are placed. For the sake of clarity, the left lung has been removed and a clamp placed on the left bronchus. The inserts show the formation of the flap from the wall of the left bronchus.

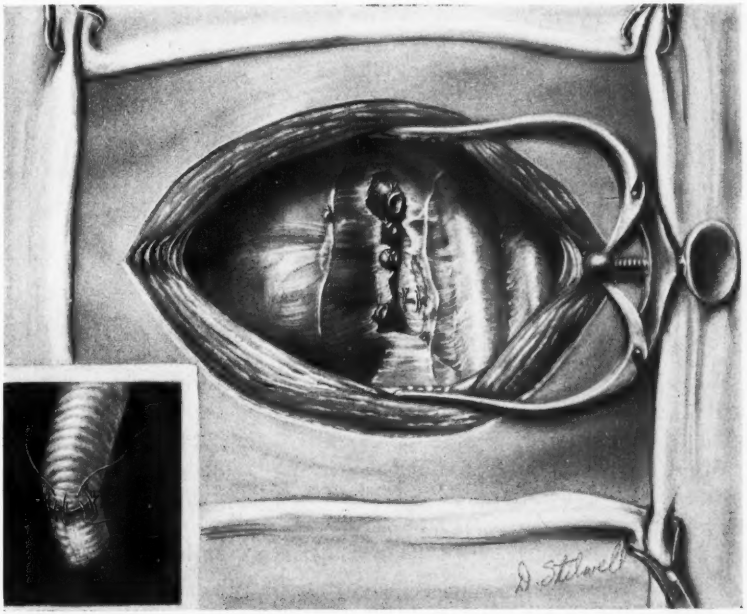

Fig. 2.—Left pneumonectomy and closure of bronchus completed. Insert shows detail of tracheal closure.

flap is correctly formed and the sutures are well placed, three to five sutures usually suffice for complete closure. Sometimes more are needed, and occasionally the incision has been closed with a continuous silk suture. Adequacy of closure is gauged by the nonescape of air from the suture line. The result of this method is to convert the trachea into a tube without bifurcation by the utilization of a semi-elliptical flap of bronchial wall from the operative side. This flap is composed of the correct tissues and has adequate circulation. The flap fits into position easily because the incision which forms the flap divides the cartilaginous rings, thus preventing the springlike action of the intact rings.

Fig. 3.—Dog killed seventy-two days after left pneumonectomy. Note that the hypertrophied right lung and heart completely fill the thoracic cavity.

Following the closure of the trachea, the pleura is brought over the mediastinal opening. Rather than use sutures which might enter the pericardium, it was found practical to unite the posterior pleural edge, grasped in a hemostat, to the ligated stumps of the pulmonary veins by means of silk ligatures. The chest is closed tightly, care being taken to approximate the spread ribs. At this stage the animal will begin breathing spontaneously and the anesthesia is discontinued.

The first two dogs died during the operation as the author was learning how to minimize the time during which the trachea is open. A third

dog died during operation from complete obstruction of the trachea as a result of an attempt to use a different type of occlusive suture. All of the remaining thirty animals survived operation. A tracheal fistula, an invariably fatal complication in dogs, developed in only three. Three dogs died of extensive pneumonia, and five of distemper, but in these animals, as in the remaining nineteen which were killed upward of seventy days after operation, there was complete healing of the trachea both grossly and microscopically.

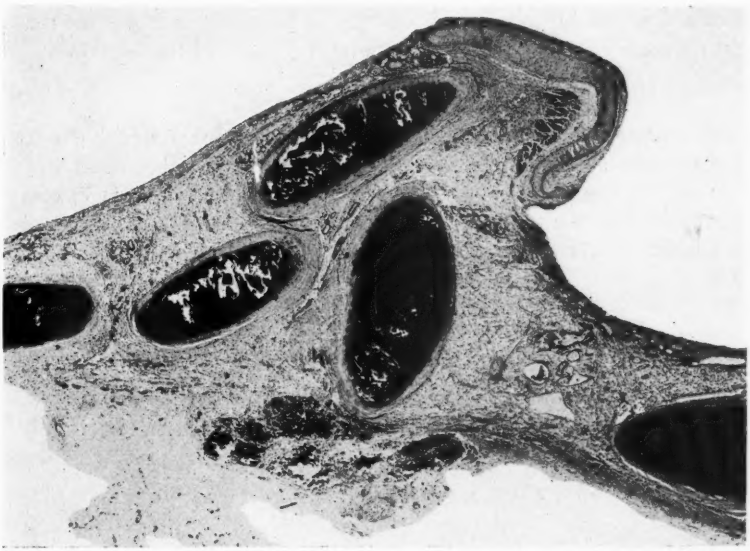

Fig. 4.—Low-power photomicrograph showing healing of trachea in dog seventy-two days after pneumonectomy (Fig. 3). Note the silk sutures along the outer portion of the trachea at the site of healing.

It is difficult to account for the three failures. All three dogs were operated upon during the same morning, all underwent total right pneumonectomy, all developed a wound infection (the only septic chest wounds of the series) and all died on the fifth day after operation. Carelessness in carrying out the method or a serious break in aseptic technique was responsible.

DISCUSSION

The criticism may be made that this method is technically difficult, and it is true that in dogs the bronchus may be closed by easier methods. Simple ligation or inversion of the bronchus yields good results in dogs but not in man. It may be argued that infection will result from momentary opening of the trachea. Infected material, however, may easily be prevented from coming out of the lung to be removed by placing a clamp on the bronchus distal to the proposed line of incision.

Probably less contamination will result from the temporary opening of the trachea than from the sloughing of the bronchus distal to the encircling ligature when that method is employed. Furthermore, less devitalized tissue is left in the wound, and healthy tissue will resist successfully a small amount of bacterial contamination. An added advantage is that the small pouch or blind stump of bronchus is obviated by this method of flap closure. Finally, it may be argued that this method, in utilizing a portion of the bronchial wall from the operative side, fails to remove a sufficient amount of bronchus to cure a bronchiogenic carcinoma near the bifurcation. That may be true, but it is just as true that no other method now in use removes any more of the bronchus.

SUMMARY

Pneumonectomy has been performed on thirty-three dogs, with closure of the tracheobronchial junction by means of a flap of bronchial wall. This method has proved satisfactory in dogs, and has resulted in complete healing of the tracheal opening in twenty-seven of the thirty animals which survived operation.

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1. Crafoord, Clarence: On the Technique of Pneumonectomy in Man, Acta chir Scandinav. **81**: supp. 54, 1938.